# Keeping up with technology

## A pilot study of TAFE and the manufacturing sector

*Phillip Toner*

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## A pilot study of TAFE and the manufacturing sector

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The views and opinions expressed in this document are those of the author/project team and do not necessarily reflect the views of ANTA or NCVER.

# Publisher's note

At the time of the study for this publication, industry skills councils were known as industry training advisory bodies. The earlier title is maintained in this report for historical accuracy.

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# Key messages

- Most studies on innovation have focused on emerging industries and the ability of the vocational education and training (VET) sector to help them meet their skills and knowledge needs. This study focuses on the manufacturing sector, a traditional client of vocational education and training, and examines in particular how well technical and further education (TAFE) teachers maintain the currency of their skills, and support innovative work practices and the adoption of new technologies in the sector.
- The manufacturing sector has a particularly high level of innovation and a large VET-trained workforce, so it is imperative that TAFE maintains not only current skills and knowledge about the latest technology, but also its capacity to support innovation in the sector.
- TAFE teachers are involved in seeking information about, and supporting, innovation and technical development through a wide variety of approaches outside their normal teaching activities. However, this role in technology diffusion, deployment and innovation goes largely unnoticed and it has become even harder as work levels have intensified and key staff numbers have been reduced.
- Both TAFE teachers and the employers they service are satisfied with the currency of teachers' skills and knowledge. Neither are satisfied with the currency of equipment for teachers, nor with the formal professional development available for maintaining that skills and knowledge currency. However, industry associations have concerns about staff qualification levels.
- Teaching staff surveyed note that there are no formal mechanisms for evaluating new technologies and equipment for incorporation in teaching programs.
- The role of the VET sector in technology diffusion needs to be more widely acknowledged. It needs to be more integrated into national innovation policy and research and development programs because of its dual role of ensuring that appropriate training is available and promoting new technologies to small and medium-sized enterprises. The VET sector also needs to acquire more capacity to monitor technological trends and innovation in industry, and to help assess the implications of this for vocational education and training.

# Executive summary

This report seeks to determine how technical and further education (TAFE) teachers can maintain the currency of their skills and knowledge, and support innovative work practices and the adoption of new technologies. It is one of the first research projects undertaken in Australia to look at innovation in an established industry such as manufacturing, rather than a new or emerging industry, and should thus be regarded as a pilot study. In addition, sample sizes for the surveys were not large, so results cannot be generalised to the entire TAFE system. Finally, the absence of a broad range of national data on TAFE teacher numbers, qualifications and capital investment methods meant that it was not possible to objectively test some of the claims of survey participants.

In recognition of the growing importance of 'productive knowledge' in national prosperity and competitiveness, many countries are devoting more support to the creation and deployment of innovation. In Australia the vocational education and training (VET) sector is largely excluded from national innovation strategies. In other countries, such as Finland, Germany and the United States, public vocational colleges are an important part of such policies. The colleges run technology deployment programs which encourage industry to adapt well-established technologies and raise both the level of productivity and the capacity for product and process innovation, especially in small-to-medium-sized firms. These programs include a broad range of consultancy, technology demonstration and applied research and development functions, separate from traditional classroom teaching. They are particularly useful for small and medium-sized firms, which typically have fewer resources to identify potentially valuable technologies, to evaluate competing technologies and to adapt these technologies to the particular needs of their firms.

The study chose manufacturing programs in TAFE as its subject because previous research indicates that the manufacturing industry has a particularly high 'innovation intensity'. An innovative industry is defined as one which has 'implemented technologically new or significantly improved products and processes. Those characterised as intensive have contributed to the national expenditure on innovation after putting particular effort into research and development' (Toner 2004, p.6).

Manufacturing was also selected because it is a mature industry with well-established technologies and standards, as well as having a large workforce which has studied with a VET provider, and well-developed TAFE infrastructure. It also provides an interesting contrast with other studies which have focused on 'emerging' industries. Empirical data were collected through a survey of 18 TAFE teachers in manufacturing programs. In addition, interviews were conducted with eight innovation-intensive manufacturing firms which receive training from TAFE, and four education and training officers from a major industry association covering the manufacturing industry. The study also includes a literature review which focused on two commissioned studies addressing similar issues in the public VET system in Germany and the United States.

The survey data found that TAFE teachers used a wide range of external and internal sources to identify new technologies and associated teaching methods. The most important external sources included leading-edge users/producers/suppliers of equipment, industry associations, learners and the actual manufacturing plants. The most important internal sources were internet searches and journal circulation. Information-sharing with other intrastate and interstate colleges and professional development were also important. However, links between TAFE and universities and

cooperative research centres, which could provide important information-sharing opportunities, were viewed as weak and in need of strengthening.

Just over three-quarters of teachers indicated that there was no prescribed formal method for evaluating and selecting new technologies to be used in teaching. Formal methods were defined as activities such as surveying an industry to determine if there was a demand for training, evaluating the technical superiority of competing technologies, or formally calculating costs against expected revenues. Although some teachers included aspects of this information in written requests for the acquisition of technologies, most teachers confirmed that there is no prescribed procedure or process to follow for evaluating or selecting technologies.

The acquisition of new technologies typically occurs by direct purchase through tender. Other methods of acquisition, such as leasing or sharing costs with industry, are not generally used. Important sources of equipment and consumables included donations from industry, the armed services, equipment suppliers and large firms which had established close relations with TAFE. Some courses are heavily reliant on donations from industry for their continued operation, and this dependence appears to be increasing.

Once new equipment or software is acquired, teachers need to be educated in the new technology. This can occur in a number of ways, such as accessing training from equipment suppliers, or learning internally at TAFE through developing learning materials for the new equipment. In addition, recruiting new staff who are familiar with the new technologies, seeking advice from industry and participating in return-to-industry programs can help teachers in the process. Half the teachers claimed that modification of equipment and software occurs in response to the needs of the teaching environment, and a quarter suggested modifications are made to meet the needs of prospective employers of students.

On the basis of the surveys of teachers and employers, it is evident that teachers are involved in technology deployment and even applied research and development with firms through a wide range of processes, as well as classroom teaching. For example, some small and medium-sized enterprises purchase equipment based on the needs of TAFE because this offers a number of benefits to all concerned. It ensures a ready availability of training and technical advice, and that teachers are involved in product and process development through consultancies and return-to-industry programs. In addition, TAFE colleges can run demonstrations and exhibitions of equipment by suppliers, and universities can become involved in research and development projects.

The involvement of teachers in this broad range of deployment and product and process improvement in firms is an important finding since, as noted above, the TAFE system is not generally recognised by government as part of the Australian innovation system. It is also largely absent from government innovation or technology deployment programs. As is explored later, there appear to be increasing barriers to the TAFE system's ability to take part in this process. These include the restructuring of some TAFE departments, the difficulty of maintaining its current knowledge base, and the uncertain role that teachers play in technology deployment.

Only two of the teachers interviewed were satisfied with the capacity of TAFE to identify new technologies. However, most teachers felt their qualifications and knowledge were satisfactory for their current role. Teachers believed that, despite an increasing number of barriers to preserving the currency of their knowledge and skills, they were still managing to maintain satisfactory standards.

Barriers identified by the teachers included inadequate resources in terms of reduced staff numbers, an inability to maintain the currency of equipment, and reduced access to professional development and return-to-industry programs. These barriers are interdependent because capital and recurrent funding are linked to student numbers which, in the manufacturing industry, have declined over the last decade.

Other impediments include reduced information dissemination regarding new technologies, due to the closure or downgrading of central agencies within TAFE whose job it was to collect, analyse and disseminate information on new technologies and develop learning materials. It is also due to the application of the National Competition Policy to TAFE colleges, which makes them compete for public and private training contracts. Teachers believed that this competitiveness between colleges meant that it was no longer in their interests to share information and resources as had occurred in the past. Another point raised by some of the teachers was that the typical age of their colleagues was in the early-to-mid-fifties. Thus, many teachers have not worked in industry for some time and their technical qualifications may also be out of date.

Finally, teachers criticised both training packages and competency-based training. They believed that training packages were too slow to incorporate new technical development, while competency-based training did not give priority to teaching the theory underlying production processes. These issues, amongst others, have been considered in the recently published review of training packages undertaken by the Australian National Training Authority (ANTA). The review emphasised the importance of incorporating generic skills, occupational specific knowledge and, where appropriate, 'higher-order skills' (Schofield & McDonald 2004, p.17).

Employers and industry association representatives agreed with the teachers that TAFE equipment needs to be upgraded to meet industry standards. Industry association representatives also expressed concern at the adverse effect of competition between colleges, although opinions were divided over whether the loss of central TAFE information agencies had impacted on information-sharing about new technology. Again, employers and industry association representatives did not agree about teacher qualifications and skills: employers were satisfied, but industry association representatives were not. Representatives were also concerned that some teachers may be conducting courses above the level of their own technical qualifications. Both employers and industry association representatives were satisfied with training packages, and industry association representatives rejected teachers' criticisms of competency-based training.

The study concludes that vocational education and training plays an important role in innovation, and this needs to be more widely recognised. For example, VET skills are incorporated in product and process innovation, and the public VET system contributes to technology diffusion. For this recognition to occur, the public VET system in Australia must be given a role to play in the development of national innovation policy, technology diffusion programs and Australian Bureau of Statistics (ABS) data collections on innovation, and research and development.

This study supports the recommendation of Ferrier, Trood and Whittingham (2003, p.43) that the VET system must develop the ability to monitor technology trends and undertake analysis of the effects of innovation on vocational education and training. In addition, it must collect data on the capacity of the system to meet the innovation requirements of industry.

Maintaining an up-to-date VET system requires additional resources to take on significant new roles. These include accessing more current equipment, employing teachers with more recent extensive industry experience—some of whom have higher technical qualifications—accessing more return-to-industry programs, and negating the adverse effects of excessive competition between colleges. There are also some potentially important efficiency gains to be achieved through changes to current procedures. For example, the introduction of a formal system for identifying and evaluating the relative merits of technologies to be purchased could improve the quality of new equipment. This is an issue which should be further investigated.

Other suggested strategies to improve the currency of equipment available to TAFE for teaching purposes include leasing instead of purchasing equipment and forming training partnerships with industry to share costs or 'buy time' on equipment. These methods are not new and are, in fact, being implemented in some colleges. However, the effectiveness of the processes need to be evaluated and possibly developed further.

# Background to the study

This report seeks to build on other work which has examined the links between vocational education and training (VET) and innovation.[1] The report *Innovation agents: Vocational education and training skills and innovation in Australian industries and firms—Volume 1* (Toner et al. 2004a) was the first comprehensive Australian study of the role of VET occupations and skills in the design and implementation of innovation in Australian firms. It identified concerns about the capacity of the VET sector to maintain current skills and equipment. The present study also complements *Going boldly into the future: A VET journey into the national innovation system* (Ferrier, Trood & Whittingham 2003). This is one of the few studies in Australia on the subject of vocational education and training and technology diffusion, or how the VET sector contributes to the spreading of technological skills throughout industry. The report focused largely on cooperative research centres (CRCs) and their links with vocational education and training. The report highlighted that, in general, the 'links between the VET sector and the co-operative research centres are weak or informal. There are few strong links' (Ferrier, Trood & Whittingham 2003, p.27). More generally it found that the links between TAFE and national innovation policies and programs need to be strengthened.

The present study is one of the few in Australia or internationally to focus specifically on the difficulties teachers in a public VET institution face in keeping their skills, knowledge and teaching equipment up to date, and the strategies they employ to overcome these barriers.

## Scope of the study

The purpose of this research is to describe and evaluate the processes which technical and futher education (TAFE) institutes use to identify, select, acquire, and adapt new technologies from industry to become part of their teaching programs. The report also looks at the ways in which institutes seek to keep their equipment, curricula and teaching skills current. Interviewees in three states in Australia provided information and feedback.

The report makes important findings relevant to a wide range of people, including teachers and students in VET institutions and universities, those working in industry, and policy-makers.

This is a pilot study with the TAFE sector and the results are provisional for a number of reasons. It is the first study on this topic undertaken in Australia, the survey data are restricted to selected manufacturing industries, and the survey base is relatively small. Further work is required to undertake similar studies in other teaching areas within TAFE, in other states and other provider types, to investigate many of the interesting and policy-relevant findings of the research.

[1] VET qualifications are defined as Australian Qualification Framework (AQF) levels I–IV or V. VET occupations are defined as Australian Standard Classification of Occupations (ASCO) Major Group 3 Associate Professionals to Major Group 9 Labourers and Related Workers.

# Research questions

The specific research questions addressed in the report are:

- What are the key national and selected international patterns and institutional bases for knowledge diffusion, or the extent and speed with which knowledge is spread, in the VET sector?
- What are the formal and informal institutions and processes used by TAFE to identify key technological innovations? What are the institutions and methods used to identify the impact on, and implications for, TAFE of these new technologies? What methods and criteria are used to select amongst competing technologies and how are priorities for acquisition set? How are these innovations sourced and acquired? What are the institutional arrangements and methods used to adapt TAFE operations and skills to these new technologies? How are the new technologies adapted to TAFE operations?
- Are the institutions and processes used to identify, select, acquire, and adapt innovations adequate? Are the resources devoted to the task adequate?
- What are the impediments to improving the institutions and processes to identify, select, acquire, and adapt innovations?
- How can these impediments be efficiently redressed?
- How well do state-based training intermediaries establish networks with knowledge producers in other states and coordinate knowledge diffusion with training intermediaries in other states?
- To what extent should TAFE be a leader rather than a follower in the introduction of innovation?

# Project methodology

This report uses two principal sources of data. Firstly, a brief review is provided of Australian and overseas literature on knowledge acquisition and diffusion in public VET institutions. It must be noted that there is a lack of material related to the specific research questions used to frame this study. There is, however, a large amount of literature on other aspects of vocational education and training and innovation. These reports look at topics such as innovation in VET teaching and learning, and provide case studies on the links between vocational education and training and particular innovative firms. This literature is only tangentially connected to the concerns of the present study. Given the lack of literature relating to the research questions, and to provide an international perspective, relevant studies were commissioned on innovation and the VET sector in Germany and the United States.[2] These two countries were chosen because they are known to have well-established, although distinct, institutions and processes for VET training.

Secondly, data were collected through 18 semi-structured, face-to-face interviews with key respondents in TAFE in four manufacturing fields across three states: New South Wales, Victoria and Queensland. A semi-structured interview schedule was used for the interviews, consisting of both multiple-choice and a fewer number of open-ended questions. The format allowed the collection of core common data items as well as data items specific to each interview. The format also allowed the pursuit of interesting and relevant lines of inquiry as the interviews proceeded.

The respondents were selected from four program areas in various TAFE institutes which service the following innovation-intensive industries: food processing, metallurgy and foundry, computer-controlled machining, and communication systems.[3] The sample included TAFE staff involved in

[2] Dr Gerd Gidion, Institut of Labour Research, Fraunhofer Institut prepared the German study and Dr Jim Jacobs, Community College Research Centre, Columbia University prepared the study on the United States.

[3] Manufacturing is rated second highest out of 13 industries in a composite index of innovation (Toner et al. 2004a, p.32). Within manufacturing industries these four industries are also rated highly.

day-to-day teaching, former teachers who are currently involved in curriculum development, and staff teaching in dedicated centres designed to teach and promote more advanced technologies.

The report focuses on the manufacturing industry because it is a mature industry with many leading-edge firms, as well as having a large workforce trained in the VET sector and VET infrastructure. It also has well-established standards regarding production technologies and product quality, multiple 'knowledge producers', and strong interactions between these producers and firms. Other studies, notably Ferrier, Trood and Whittingham (2003), have found that most or all of these characteristics are absent from 'emerging' industries, such as the photonics industry.

Knowledge producers involve a broad range of public and private institutions, which contribute new knowledge to the transfer and diffusion of existing productive knowledge within Australia. They include universities, cooperative research centres, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), private firms undertaking research and development, and multinational enterprises which transfer technology within Australia.

To gain an industry perspective on these issues, telephone interviews were arranged with four education and training officers from an industry association with coverage of the manufacturing industry, and eight leading manufacturing firms across the four industries that receive training from TAFE. These interviews pursued matters such as TAFE's capacity to address the needs of leading-edge companies, and suggestions for addressing any constraints on this capacity.

One of the main difficulties confronting this study is the absence of a broad range of national data on TAFE related to how they acquire new technologies and keep skills and equipment up to date. This made it difficult to objectively assess the claims of survey participants. For example, there are no readily available national standardised disaggregated time series data on field of study regarding TAFE teacher employment, teacher qualifications, or capital expenditure and capital depreciation. There are also no indices or benchmarks for determining the currency of plant and equipment or how well they meet the current technical requirements of industry. Without such data, it is not possible to accurately monitor trends in innovation performance and resource allocation within the TAFE system.

# Links between VET and innovation

There have been few studies on the specific research questions framing this study in terms of how the VET system identifies, selects, acquires and adapts new technologies. There is, however, a very considerable body of literature on other aspects of vocational education and training and innovation. These include:

- variations between countries in the quality of VET training, as a reason for international differences in the composition, productivity and quality of manufacturing and services output and trade
- case studies of links between particular innovation-intensive firms and particular TAFE colleges or institutes
- new technologies and their impact on VET teaching and learning systems such as e-learning
- vocational education and training and its role in national systems of innovation.

Some of this literature and its implications are discussed below.

## The role of VET in explaining international differences in industrial innovation and productivity

A country's capacity for product and process innovation is of increasing significance in national economies, given the increased share of national output that is exported and the rapidly increasing knowledge and innovation-intensity of these exported goods and services (Guerrieri 1999, p.156).

There is now a very considerable body of literature on the crucial role of vocational education and training in determining the pattern and pace of industrial development and, in particular, the capacity for introducing product and process innovation (Prais 1995; Mason, Van Ark & Wagner 1996; Keep & Mayhew 1999; Hall & Soskice 2001). The extensive literature on this topic is reviewed in Toner et al. (2004a). Skilled production, trade and technician occupations are essential in the generation, design, installation, adaptation and maintenance of new technologies. For example, Australian managers believe that those working in production occupations contribute far more than research and development and technical staff to 'initial ideas' for technological innovations, as well as taking part in their further development throughout the life of the innovation project (Toner et al. 2004a, p.47). There is also a body of Australian evidence which shows that, as a result of changes to work organisation methods and the use of new computer-controlled production equipment, there is growing demand for higher-level accredited skills at both a plant operator and trade/technician level (Toner & Wixted 2002).

There are large disparities in the skill levels and qualifications of the VET-trained workforce (production, trade and technician-level occupations) across countries. These disparities have been shown to contribute to international productivity differences in manufacturing of up to 100%, as well as variances in the quality of output and capacity of firms to introduce product and process innovation (Prais 1995; Anderton & Schultz 1999).

A number of factors have been identified which translate national differences in the quality of VET-trained workforces into national differences in productivity and innovation. Firms in countries with

a comparatively large proportion of their production workforce with higher-level VET qualifications reveal the following characteristics:

- lower defect and re-work rates
- lower ratios of indirect labour such as forepersons, supervisors, quality checkers and clerical support to direct labour
- higher plant capacity use as a result of much lower rates of machinery breakdown due to preventative maintenance undertaken by machinery operators and staff skilled in this area
- greater capacity to introduce and efficiently operate computer-controlled machinery that facilitates product customisation and product innovation (Prais 1995; Mason, Van Ark & Wagner 1996).

At its most fundamental, the supply of VET skills is influential in determining not only what goods and services are produced in a national economy, but how they are produced. 'Firms' product market choices are constrained by the availability of necessary skills' (Estevez-Abe, Iversen & Soskice 2001, pp.38–9). For example, the supply of skills can influence the product market strategy of firms: whether to produce standardised products that compete largely on price, or to employ more sophisticated production methods that compete on the basis of quality and customisation (Keep & Mayhew 1999, pp.7–8). Firms 'producing high quality, specialised goods and services require a well-qualified workforce capable of rapid adjustment in the work process and continual product innovation' (Finegold & Soskice 1988, p.21).

This literature supports the recognition of vocational education and training as a key influence on national innovation policies and programs.

# Case studies of links between VET and innovative firms

Toner et al. (2004a) conducted eight case studies of successful interaction between TAFE and innovation-intensive firms. The firms were from a range of industries, such as manufacturing, telecommunications and health. They were assessed as innovation-intensive on a number of criteria, such as rates of research and development and expenditure on training and capital investment. These firms rated the service provided by TAFE very positively. One of the reasons given for this positive assessment was the close consultation between the firms and TAFE, especially in the customisation of training to the particular firms' requirements. An example of this customisation was the flexibility which TAFE allowed in the times and places where training was delivered to the firms' employees. The strength of the relationship was also indicated by the firm upgrading the technical skills of teachers, to enable them to deliver up-to-date training adequately to the firm's employees.

However, it is important to recognise two structural factors particular to innovation-intensive firms and industries which underpin the cooperation and satisfaction with training evident in the case studies. The first is that innovation-intensive firms are both larger (measured as number of employees) and, on average, invest more in training per employee than non-innovation-intensive firms. (Similar findings are reported in Dockery 2001.) Secondly, the large size of the case study firms created a level of demand for training that made it economically feasible for TAFE to both customise its courses and invest in upgrading the skills of its teachers for the particular clients. These larger firms also have the internal management resources necessary to establish close relations with TAFE.

In contrast, Whittingham (2003) identified a number of impediments to the formation of linkages between vocational education and training and innovation-intensive firms. These results came from 14 case studies of 'start up' companies in the photonics industry. The barriers to the VET sector meeting the training needs of the industry were mainly due to the newness of the industry, its small size and the consequent lack of knowledge within the sector of the industry's needs.

# Impact of new technologies on VET pedagogy

This literature identifies how new technologies affect teaching. The studies typically involve the application of generic technologies, such as information and communications software, to the needs of particular TAFE client groups such as distance or disabled learners. These studies differ from the present report in that they focus on the selection and adaptation of technologies specifically to improve pedagogies, or ways of teaching and learning. In the present study the focus is on how teachers identify, acquire and adapt technologies typically in use in workplaces. In this instance, the teacher interest in the technology is driven primarily by the need to keep up to date with technological trends in industry, not with improving methods of teaching and learning. Nevertheless, these studies are relevant in that they confirm the considerable effort required in adapting new technologies to a teaching environment (Guthrie & Gibb 2001; Mitchell 2003).

A related topic of literature identifies the reasons why innovation in pedagogy is encouraged or discouraged in particular institutions and workplaces. Studies such as those of Sadler (2001), drawing on management theory, seek to identify the institutional bases for 'educational entrepreneurship'.

## VET and national systems of innovation

In Australia the public VET system has a central role in the initial training and continuing skills upgrading of production, trade and technical occupations. However, as noted in Toner et al. (2004a), the VET sector is largely absent from federal government policies and programs on innovation and technology diffusion. The VET sector receives little attention in the principal government statement on innovation policy, *Backing Australia's ability: An innovation action plan for the future* (Commonwealth of Australia 2001), and receives only a few incidental mentions in the comprehensive description of Australia's innovation system, *Mapping Australian science and innovation: Main report* (Commonwealth of Australia 2003).

The principal federal government technology diffusion program, the Innovation Access Programme, is 'designed to foster innovation and competitiveness by the increased take up of leading edge technologies and best practice processes by Australian firms, particularly SMEs [small-to-medium-sized enterprises]' (<http://www.iaccp-industry.gov.au>). As far as can be determined, TAFE has not been a direct beneficiary of this program. The principal beneficiaries are universities, industry associations (for example the Australian Industry Group and Welding Technology Institute of Australia), and companies. As will be discussed later, the public VET sector is also specifically excluded from ABS surveys of research and development in public higher education institutions.

This report, along with other research, suggests this focus must be broadened to recognise the key role of the VET sector in the technology diffusion process (Toner et al. 2004a; Ferrier, Trood & Whittingham 2003).

It is also now accepted that not only is new knowledge the principal factor in productivity growth, but that a key determinant of the quality of VET skills is the efficiency of the knowledge diffusion process. The efficiency of this process is crucial in maintaining the currency of plant and equipment in VET institutions and the theoretical and practical skills of teachers. Numerous studies have demonstrated the role of technology diffusion—from knowledge producers, to intermediaries (the VET system), and finally to end users (firms)—to be central to the creation of a 'self-sustaining high-skill ecosystem' (Finegold 1999, pp.77–9). The literature shows that the key producers of new technical knowledge are universities, public/private research institutes, capital goods producers and leading-edge firms. It also reveals that whether this information flows efficiently between groups is largely dependent on the extent and intensity of the formal and informal communication between the 'producers', VET intermediaries and users of this knowledge (Rosenberg 1982, pp.121–2; von Hippel 1988; Midgley, Morrison & Roberts 1992; Finegold 1999). The acquisition of new technology by VET intermediaries and firms is not a passive process, but entails the adaptation of particular technologies to particular teaching requirements. The literature identifies the 'active

involvement in technical change … by firms, industries and economies which acquire technology developed elsewhere' (Bell & Pavitt 1999, p.84). In addition, knowledge acquisition and diffusion is expensive and time-consuming, with intermediaries and end-user firms both having to search for relevant innovations and adapt this new technology to their particular circumstances.

Curtain (2004) provides an overview of what constitutes a national innovation system and the role played by vocational education and training in such systems in two national case studies: Finland and Singapore. National innovation systems are comprised of public and private institutions and the incentive structures (government grants, tax rates etc.) that promote the generation and diffusion of economically useful knowledge. The success of such systems depends on a number of key elements. Most importantly, it is necessary to have a 'critical mass' of producers and users of knowledge so that the generation and application of any innovative technology is economically viable (Curtain 2004, p.7). The quality of the interactions or 'knowledge flows' within and across the public and private institutions is also crucial (Curtain 2004, p.19). In addition, larger firms are more capital-intensive and have a much greater propensity than smaller firms to invest in innovative activities such as research and development and structured staff training.

The idea of a national system of innovation applies not only to the 'high technology' sectors such as biotechnology and software development, but also to traditional activities like manufacturing and agriculture. Curtain reveals that industries such as:

> … petroleum refining, pulp and paper, textiles, or food and beverages can also be highly innovative, drawing on many fields of knowledge … [such industries] are of far greater economic significance than high technology sectors such as aerospace and pharmaceuticals.
>
> (Curtain 2004, p.17)

These are also industries in which the VET sector is the principal supplier of education and training. The rapidity of change in innovation-intensive industries, even 'traditional' industries, means that the VET sector must be increasingly active in identifying these new technologies and assessing their implications for training provision (Curtain 2004, p.17).

According to Curtain (2004), the principal implications of the shift to a knowledge economy for the Australian VET system are:

- ✧ providing access for vocational education and training 'to government provided research and development funding … to link the VET sector in Australia with innovation' (p.24)
- ✧ improving standards in vocational education and training by the 'use of international benchmarks'. Such benchmarks include links for staff and students with leading overseas VET institutions (pp.24–5)
- ✧ expanding the use of distance learning (p.25).

One of the more interesting findings relates to their case study of Finland. In the early 1990s this country radically reformed its VET sector, with around 80% of the existing public VET capacity converted to degree-granting polytechnics (Curtain 2004, p.31). The report does not explicitly address whether a similar upgrading of the Australian VET system is warranted.

## VET and emerging industries

This present research is linked strongly to the work on innovation by Ferrier, Trood and Whittingham (2003), which focused primarily on 'emerging' industries, notably photonics. (The Department of Industry, Science and Resources [1999] report identifies the key characteristics of these industries.) Ferrier and colleagues found that the process of diffusion between researchers and the VET sector was usually quite weak. In contrast, this current research is based on four mature manufacturing industries with strong links between industry and TAFE. The present study pursues many of the key recommendations for further research in Ferrier, Trood and Whittingham (2003, p.93) relating to the links between innovation and vocational education and training.

Ferrier and colleagues argue for recognition of the importance of the VET sector in 'supporting the timely and efficient introduction of new knowledge into the national innovation system to support the introduction of goods and services based on new technology' (Ferrier, Trood & Whittingham 2003, p.86).

They also give a number of reasons for the generally poor links between TAFE and cooperative research centres, suggesting that these centres:

- ✧ have little understanding of VET systems and how to connect with them
- ✧ view VET course accreditation processes as too complex
- ✧ don't recognise establishing connections with VET as a performance criterion
- ✧ have lost key individuals who were able to initiate contacts
- ✧ service only a small-sized industry; therefore there is limited demand for VET courses
- ✧ produce research which is at a very high technical level and/or at an early stage
- ✧ fail to recognise the VET system as a user of either their knowledge or their products
- ✧ see connections with vocational education and training as lowering their prestige
- ✧ are faced with a lack of interest by VET personnel in establishing connections

(Ferrier, Trood & Whittingham 2003, pp.28, 71, 73, 78, 81).

These findings are echoed in the results of the present study, especially the generally poor links between TAFE and universities/cooperative research centres. This is important because the present study is focused on a mature industry, rather than an emerging one.

Thirdly, mutual benefits are identified for those cooperative research centres and VET institutions which do cooperate.[4] For cooperative research centres, links with vocational education and training provide 'access to new industry networks, to expertise and other facilities [and] training and professional development expertise'. For the VET sector, it provides:

> … personal and professional development opportunity … early access to new knowledge ensuring that teaching remains up to date. It can also lead to new opportunities providing … fee for service income. (Ferrier, Trood & Whittingham 2003, pp.27–8)

For industry more generally, the benefits of closer links between knowledge producers and vocational education and training include:

> … more timely skills development in new and existing industries … better knowledge transfer into the training system to support industry development … a reduction in the likelihood of skills gaps or shortages … [and] a culture of innovation in the VET sector.
>
> (Ferrier, Trood & Whittingham 2003, p.87)

These results were also replicated in the present study, with teachers identifying a number of benefits from closer ties with knowledge producers and users.

Lastly, while cooperative research centres create 'new technologies, processes, systems, equipment, tools or products' for use by industry, the effect of these innovations on the VET system is highly diverse and difficult to predict (Ferrier, Trood & Whittingham 2003, p.26). Some new products don't actually require any new skills to be adopted or maintained. Some innovations are skill or competency 'destroying' in that they 'simplify a task that previously could only be performed by experts'. This can mean that lower-skilled workers need to be upskilled to take on these new tasks, while the 'experts' need to acquire higher-level or broader skills. A new technology or product may be applicable across several industries and may therefore require a major response from VET

[4] These benefits were identified by those photonics and viticulture cooperative research centres which have strong links with vocational education and training (Ferrier, Trood & Whittingham 2003, p.27).

institutions across several different industry disciplines. Other new products may be quite industry-specific in their application. When the demand for a new product is limited, a 'formal response from education and training systems is not always required', as training can be met by the cooperative research centre (Ferrier, Trood & Whittingham 2003, p.26). Accordingly, the report strongly recommends that the VET system acquires the research capacity to undertake the analysis of the effects of innovation on vocational education and training, and suggests the type of data which is required to undertake this analysis (Ferrier, Trood & Whittingham 2003, p.43, table 4.1). These and other findings are further investigated in the current report.

Responding in part to the work of Ferrier, Trood and Whittingham (2003), important new research by Lindhjem and Royle (2004) seeks to provide guidance to TAFE managers and other providers 'to identify the point at which … [emerging industries] warrant the development or modification of training' (2004, p.155). They propose an 'opportunity analysis model' offering TAFE managers a strategic approach based on a number of factors. These include an assessment of the growth potential of the emerging industry, how well the emerging industry's training needs fit within the strategic direction of the college or institute, the scale of competition to TAFE in the provision for training, and the capacity of the TAFE system to deliver the prospective training in terms of teacher skills and infrastructure.

One of the key findings of the present study is the apparent absence of formal procedures for identifying, selecting and acquiring new technologies in TAFE. These findings support the work of Lindhjem and Royle (2004), in terms of the need for TAFE to adopt a more strategic and systematic approach to technology acquisition.

# International perspectives on public technical colleges as technological intermediaries

This section draws on a number of studies, including work commissioned for this project by experts on the issue of vocational education and training and new technology in Germany and the United States. It particularly seeks to compare and contrast Australian and international patterns and institutional bases for knowledge diffusion in the VET sector.

## Broad international trends in VET and technology deployment

Before considering the two commissioned studies, a brief overview is provided of the changing role of technical colleges in technology deployment for the more advanced economies of the Organisation for Economic Co-operation and Development (OECD). Several key trends have emerged from this process. During the 1990s, the direction of public policy in the fields of technology and education broadened to encompass both the traditional concerns of technology generation through support of public and private research and development, as well as showing increasing support for technology deployment. The previous technology generation policies:

> … neglected … the large majority of the world's value-adding companies, the small and medium sized employers, whose requirements for technology and innovation were something less than leading-edge research and who lacked the capacities and connections to effectively adapt already commercially available technologies and proven innovations.
>
> (Rosenfeld 1998, p.2)

Public vocational colleges have since been targeted as key institutions for such technology deployment.

There has also been a trend over the last two decades for much stronger integration between technical colleges, industry policy and economic development agencies at a national and regional level. Citing examples from the United States and Ireland, it was found that technical colleges are often highlighted in the 'marketing' activities of development agencies and 'it is common for

development agencies to bring potential investors to the colleges, and most inward investment trips abroad include technical college administrators' (Rosenfeld 1998, p.26). Similarly, Jacobs (2003) emphasises the long-standing, but increasingly important, function of economic development performed by public colleges. This role involves both providing skills to attract new investment to the regions in which they operate, and upgrading the skills of existing firms.

Finally, 'technical colleges are emerging as critical factors and key institutions in technology based development to fill industry's requirements for more highly skilled and technically proficient workers' (Rosenfeld 1998, p.1). This is based on an acceleration in the rate of technical change, as well as large shifts in the occupational structure of advanced economies towards more skilled occupations and a 'growing preference among employers for … intermediate credentials' (Rosenfeld 1998, p.10). Indeed, in some areas in the United States the number of university graduates training in technical colleges exceeds the number of technical college students enrolled in courses designed to gain them university entrance (Rosenfeld 1998, p.10).[5]

## Technical colleges as knowledge diffusers

By comparison with universities, technical colleges have certain features which make them particularly suited to the role of technology deployer or innovation intermediary. These include:

- a more explicit economic development role than universities. In general, technical colleges are concerned with technology deployment because they want to teach theoretical and practical skills which will be immediately applied. Universities are more concerned with enabling students to acquire and apply a body of theory, and with making advances in this body of theory. In the words of one TAFE teacher interviewed for this project: 'universities design, we maintain'
- a greater focus on meeting the particular needs of industry and students in the region in which the colleges are located. This is due, in part, to the fact that in many regions colleges 'are the leading source of technical expertise … and the core of regions' knowledge infrastructure'. This applies especially in their relationship with small and medium-sized enterprises
- a direct link to the investment activities of firms. Acquisition of new plant and/or the introduction of new products invariably involve training. In most instances this training needs to be customised and is typically supplied by technical colleges or equipment suppliers
- a greater 'flexibility and adaptability' than universities
- an 'under-rated and undervalued contribution' in their role as 'intermediary institutions … putting companies and services in touch with one another and encouraging technology transfer and information exchange'. (Rosenfeld 1998, pp.4–8)

Drawing on his earlier 1995 report, and that of the United Kingdom's Further Education Development Agency (James & Clark 1997), Rosenfeld (1998, p.9) classified 'the activities at technical colleges that relate to or support technology adoption and diffusion' (see table 1). This system is not only comprehensive but, based on the responses to the survey of TAFE teachers undertaken for this project, it also applies particularly well to the broad scope of activities within the Australian TAFE sector. While it is clear that many of these functions are not within the formal range of teachers' duties, the survey gave examples where almost all these activities took place.

However, as will be discussed later, there are concerns regarding the capacity of the system to continue to fulfil these functions.

[5] Similar trends are evident in Australia. In the late 1990s, of all people with qualifications employed in innovation-intensive industries, 27% had a diploma or skilled vocational qualification. However, 45% of all qualifications most recently attained were a diploma or skilled vocational qualification (Toner et al. 2004a, p.62). Moreover, a key finding of this study was that, for a number of reasons, innovation-intensive firms have a strong preference for VET training which results in the granting of formal qualifications.

**Table 1: Classification of activities at technical colleges**

| | |
|---|---|
| Education: | ✧ Rigor, articulated with higher education |
| Gateway to the workplace | ✧ Comprehensive programs |
| | ✧ Working with industry |
| | ✧ Targeting clusters of firms |
| | ✧ Educating disadvantaged youth |
| | ✧ Effective recruitment |
| Upgrading skills and retraining: | ✧ Customised and contract education |
| Adapting to technology | ✧ Forming training networks |
| | ✧ Using distance learning |
| | ✧ Teaching soft technologies/skills |
| | ✧ Educating managers |
| | ✧ Training displaced workers |
| Technology intermediaries: | ✧ Technology centres/teaching factories |
| Accelerating deployment | ✧ Technical assistance |
| | ✧ Industry sector hubs |
| | ✧ Host for technology services |
| | ✧ New business incubators |
| Creating strategic alliances: | ✧ Forming alliances with industry |
| Learning companies and learning communities | ✧ Consortia with other colleges |
| | ✧ Cooperating with development agencies |
| | ✧ Facilitating intra-firm learning |

Source: Rosenfeld (1998, p.9)

## Impedients to VET in technology diffusion

Importantly, Rosenfeld (1998, pp.35–7) also identifies a number of impediments to the VET sector performing these technology diffusion roles. The impediments include:

- ✧ concern over status, which stimulates technical colleges 'to become polytechnics and polytechnics … to offer post-graduate degrees'. The essential services offered by vocationally oriented technical colleges to regional economies may be lost in such changes. This factor may be important overseas, such as in the United Kingdom, but it is not an important factor in the survey results in the present study. None of the teachers in the present study suggested that a substantial rise in the average level of training at TAFE is required or that TAFE should be directly competing with universities
- ✧ reduced student numbers and falling quality of students is occurring in 'many OECD countries'. This is 'attributed to parents encouraging their children into academic tracks … manufacturing employment is considered blue collar and has lower status among youth, even if wages are much better'. This is occurring despite the problem of skill shortages for college-trained technicians. Declining student numbers was highlighted by the survey respondents as a problem, given that funding for teaching staff and equipment is linked to student intake
- ✧ resistance to change by teaching staff 'because it requires considerable effort on their part to restructure the content, learn how to use an unfamiliar technology, or rethink the teaching process'. The industry association respondents were critical of the TAFE teachers 'resistance' to training packages and competency-based training
- ✧ maintaining the currency of equipment, which is difficult for most colleges. However, on the other hand, sometimes technology acquisitions are 'not demand driven by industry but inspired by educators' with the result that such 'centers have not met expectations and are … underutilised by SMEs [small and medium-sized enterprises] … because the equipment is more advanced and expensive than they need'. Financial constraints adversely affecting the ability to maintain the currency of equipment were identified as a problem by the survey respondents in the present study

- ✧ fragmentation and competition among education and training providers can lead to wasteful duplication of equipment and curricula development and a 'sub-optimal' size of training provider. This means that the training provider does not have a large enough budget to employ specialist teachers, invest in equipment, or undertake staff and curriculum development. Competition between colleges needs to be finely balanced so that it provides a stimulus to innovation and improved service delivery, rather than promoting waste and reduced standards of teaching. Concerns about competition were evident in the survey responses, where teachers and industry association representatives regretted the lack of cooperation between colleges and institutes and the waste of resources entailed in competing for clients.

### Redressing the impediments to technology diffusion

Rosenfeld (1998, p.38) suggests a number of changes to 'enhance' the ability of colleges to respond to and promote technology-based economic development. These responses include the need to:

- ✧ encourage alliances with other organisations. 'Alliances promote learning and sharing of resources and information that leads to effective practice'
- ✧ nurture business leadership and interfirm networking in the region in which the college is located. 'Breakfast meetings, management education programs, and technology conferences that target groups with common interests' are all part of building knowledge of, and demand for, the colleges' services. It also assists the college better to identify local needs. Any assistance in upgrading the technical and innovation capacity of the region directly or indirectly generates demand for the colleges' services
- ✧ promote 'flexible scheduling' of class times and locations
- ✧ allow and reward teaching faculty consultancies and promote return-to-industry programs. Support college teachers in working with local firms by teaching and/or assisting them to deploy new technologies or develop new products
- ✧ encourage colleges to focus on the needs of regional businesses. This specialisation is necessary if colleges are to become regional 'centres of excellence'
- ✧ allow flexibility in VET funding to encourage innovation to meet regional economic needs and devise better education and training methods. A particular problem arises if funding is tied rigidly to enrolments and does not permit 'opportunities for experimentation' and entrepreneurship
- ✧ include VET institutions in regional economic development and planning efforts; this enhances connections to the region, especially small and medium-sized businesses, which are especially dependent on vocational education and training (Rosenfeld 1998, pp.38–40).

Most of these solutions, amongst others, are supported by the survey respondents in the present study.

## Technology deployment in the United States public system of vocational education

### Background to the United States public VET system

The public VET system in the United States is highly diverse, because 'unlike most other industrialised nations, the US maintains no national vocational development system' (Jacobs 2003, p.2). The strategic direction, administration and funding are almost entirely derived from local government, state government and community support. Less than 3% of the Federal Department of Education's budget is allocated to the VET system. (By contrast, around half the total funding for TAFE in Australia is supplied directly by the Australian Government). However, a variety of federal interventions over the last three decades have been important in shaping the strategic direction of the system (Jacobs 2003, p.3).

There are around nine million students in 1200 public community colleges. The post-secondary education system in the United States is comprised of four- and two-year public and private colleges. The four-year colleges are degree-granting institutions, while the two-year colleges grant associate degrees in arts, science or applied science. They also grant one-year certificates in occupationally specific training such as welding. (Apart from training students for work in the manufacturing industry, community colleges are important because they provide training in the areas of nursing, welfare, computer technologies, and clerical and business studies. The facilities of the colleges are typically open to the wider community for meetings and artistic performances or exhibitions.) In most states, public community colleges are funded through state revenues, local government property taxes and tuition fees. Over the last two decades state and federal funds directed at improving the technical capacities of manufacturing firms have been an important source of funds for colleges, enabling them to expand their role in technical diffusion, workforce development and investment attraction. Elected or appointed 'trustees' from the local community govern the colleges. The orientation of the two-year colleges is exclusively to serve the local community, with a strong emphasis on local economic development (Jacobs 2003, p.6).

## Community colleges and manufacturing industry

There are just under 600 000 students enrolled in manufacturing-related programs in United States public community colleges, with a similar number engaged in non-credit courses. In addition, there are 'thousands of manufacturing firms who are involved with their community colleges in a variety of non-training technical assistance activities' (Jacobs 2003, p.9).

For much of the twentieth century, community colleges were primarily involved in off-the-job apprentice and technician-level training that applied to only about 10% of the manufacturing 'hourly workforce'. The highly capital-intensive Taylorist and Fordist system of work organisation resulted in a clear hierarchy of unskilled and semi-skilled workers operating a narrow range of strictly prescribed duties, involving a rigid division of labour in a system overseen by college-educated engineers. This group was largely excluded from community college education (Jacobs 2003, pp.9–10).

## A new role for community colleges

In the 1960s community colleges assumed a vital new role, one that has increased in importance in subsequent years. The southern states used community colleges as a key means of attracting established manufacturing plants from the east, mid-west and northwest. 'Community colleges would train the new workforce for manufacturers [often for free] who could be induced to leave their northern communities for a low-wage, non-union climate in the south' (Jacobs 2003, p.12).

In the 1980s a major new role for community colleges resulted from the effects of rapidly rising manufactured imports and resultant job losses. In addition, worker skills sets were profoundly altered by factors, such as the widespread introduction of computer-controlled equipment, new work organisation techniques based on quality assurance, increased worker autonomy, and the importance of teamwork (Jacobs 2003, p.13). The combined effect of large job losses and skills retraining substantially increased demands on community colleges, and reinforced their economic development function (Jacobs 2003, p.15).

Considerable local, State and Federal Government funds were directed to assist industry and the workforce to make these changes. For example, in the 1980s advanced technology centres were established as stand-alone centres on community college campuses. These centres provided both training and technical assistance, such as demonstrating the latest computer-controlled technologies

to small-to-medium manufacturers.[6] In 1991 the Federal Department of Commerce established the Manufacturing Extension Partnership, a technology diffusion and management improvement program, operating in all states. Community colleges play a major role in the technology diffusion and training efforts of these partnerships.[7] In response to the skill upgrading required by the new manufacturing technologies and changed work organisation, community colleges adopted an important new role in developing staff selection and recruitment procedures for local small-to-medium enterprises (Jacobs 2003, p.18). These new roles had important implications for the direction of community colleges:

> What is important about these approaches is that community colleges aggressively sought out relationships with particular groups of firms and specialized their programs and delivery systems to meet the needs of the sub-set of local industry. Community colleges moved from comprehensive programs to niche programs directed at specific firms who were selected on the basis of their significance to the economic development needs of the communities they served. (Jacobs 2003, p.20)

## Challenges of new technology for the community colleges

These changes to the structure and function of community colleges created tensions, centred largely on the fact that many of the customised courses in advanced technology centres were not tied to qualifications offered by the colleges, and thus could not be used as credit. This raised concerns about the absence of articulation and, more broadly, whether it was appropriate for colleges to focus on meeting the needs of selected private firms. In addition, there were concerns about students being provided with firm-specific training which could restrict their labour market mobility.

These changes also presented difficulties for community colleges in terms of maintaining the currency of teacher skills. In technology-related occupations the 'salaries paid by industry far exceed those paid by community colleges'. The solution to this problem, however, generates other difficulties. For example, a heavy reliance on part-time staff who are only on campus during their teaching hours is not conducive to knowledge-sharing or creating a collegiate atmosphere (Jacobs 2003, p.21).

In addition, the increased sophistication of production processes and work organisation methods means that 'community colleges' manufacturing programs are now entering a new and potentially difficult phase'. Five difficulties have been identified which show that community colleges need to:

- ✧ upgrade their credit courses and arrange for better articulation with four-year colleges
- ✧ adapt to the cross-skilling of technologies in mechanical, electrical and computer skills, by incorporating these combined skills in their courses. (In Australia this is referred to as mechatronics; in the United States it is known as 'mecomtronics' [Jacobs 2003, p.23])

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[6] The National Coalition of Advanced Technology Centers, the peak organisation representing the approximately 100 centres, has 'a full-time representative at the National Institute of Standards and Technology, the federal agency that supports programs for technology diffusion in the United States' (Rosenfeld 1998, p.4). (Information on advanced technology centres can be found at <http://www.ncact.org>.) There is a long history of government involvement in improving the technological capability of United States industry. During the Cold War, for example, the *Defense Education Act* (1958) provided funds to assist many community colleges in upgrading their manufacturing facilities. Many Federal Government departments such as the Department of Energy are linked to community colleges and universities through technology diffusion programs, which use the advanced technologies involved in defense-related activities to upgrade the capacity of civilian industry. For example, the Oak Ridge National Laboratory is a major Federal Government nuclear research institute, but also has an important technology diffusion function through the Oak Ridge Centers for Manufacturing Technology (ORCMT). 'ORCMT is … a place where government agencies and private industry find all the capabilities, skills, and resources needed to turn great ideas into innovative, affordable, manufacturable products' (<http://www.ornl.org>). It works with community colleges as well as private companies and universities.

[7] Rosenfeld (1998, p.4) notes that advanced technology centres also have close connections with 'advanced equipment manufacturers' who have helped colleges become equipped with 'sophisticated technology centres to both demonstrate and train for the newest manufacturing and computer technologies'.

- ✧ address difficult curriculum issues in terms of the level and depth of teaching craft skills which are increasingly being automated, but also remain important for quite large occupational groups. For example, in many areas of manufacturing, welding is performed by robots. However, technicians still need to be trained not only in maintenance and programming of robots, but also in basic welding techniques and theory to ensure they can identify any quality problems with robot welding. Traditional welding is also widely practised
- ✧ adapt to the strategic direction of manufacturing firms, which are increasingly integrating manufacturing products with a wide variety of services. This includes providing conceptualisation/feasibility studies, customisation, design, installation, training of client staff in the use of the product or equipment, maintenance and environmental services. (A 2001 report by the Australian Expert Group of Industry Studies provides a comprehensive account of these 'product service' linkages in manufacturing.)
- ✧ realise that these changes will have an important result: that 'work in manufacturing will be further based around appropriate mathematics and computer skills', and that in the United States 'new employees in manufacturing are significantly more skilled than in the past'. However, colleges and manufacturers are experiencing recruitment difficulties as 'careers in manufacturing are uniquely unappealing' for more academically oriented students (Jacobs 2003, p.23). Attracting these more able students and/or proving significant remedial training for less able students is a major challenge for community colleges in the United States (Jacobs 2003, p.25).

The survey of teachers in the present study found that many of the dilemmas identified in the United States public system apply to the Australian VET sector servicing manufacturing industry.

# Technological innovation and the VET system in Germany

## Background to the German VET system

The central element in German vocational education is the apprenticeship or dual system. The term 'dual system' reflects that the apprenticeship is based on a close partnership between the firm employing the apprentice and public VET training institutions. More broadly, it also indicates the high level of cooperation and coordination between federal and state governments, and employer and employee associations in the system.

Apprenticeships have a duration of between two and three-and-a-half years depending on the occupation, with an average of close to three years (Gidion 2003, p.1). There are approximately 345 approved 'apprenticeship occupations' (Gidion 2003, p.1). Aside from the traditional metal, electrical, motor vehicle and construction trades, apprenticeships cover information technology, clerical, medical/ dental secretaries, and sales. (As in Australia, apprenticeships constitute a written contract between the employer and apprentice, with these agreements registered with the relevant government agency.) In 2000, 58% of all apprentices were employed in just 25 of the 345 occupations (Gidion 2003, p.10). Approximately 1.5 million apprentices are currently in training, with an annual intake of around 500 000. Of the 2.1 million firms in Germany, approximately 500 000—or 23% of the total—employ apprentices. Approximately 12% of all apprentices are in occupations related to the manufacturing industry (Gidion 2003, p.9).

There are four key institutions involved in the design and management of the German apprenticeship system. The federal government is responsible for regulating training in companies. The Lander or state governments are responsible for regulating training in VET institutions and schools. Lander committees responsible for vocational education and training are tripartite in composition. On a regional level:

> … chambers of industry and commerce and the crafts chambers … are responsible for advising and monitoring companies offering training within their districts, as well as reviewing the suitability of companies and the aptitude of their training instructors. They are also charged with registering training agreements and with establishing examination boards for intermediate and final examinations. (Gidion 2003, p.5)

As a rule, the Lander are charged with supervising these chambers. In addition, Works Councils within the 500 000 firms engaging apprentices 'have rights of participation in planning and carrying out vocational training and hiring instructors' (Gidion 2003, p.5). All aspects of the apprenticeship—including duration of training, wages, type and content of training on and off the job, and quality of training—are closely regulated and monitored (Gidion 2003, p.11).

## New manufacturing technology and the German VET system

There is a broad range of changes that are 'putting the famous German Dual System … under intensive pressure' (Gidion 2003, p.1). The pressures for modernisation of the VET system are 'driven by changes and innovations at work' from a variety of sources, including scientific research and development, wider social and political changes, and changes in VET teaching and learning (Gidion 2003, p.24).

The major innovations in the workplace relate to the way it is organised. As a result of globalisation and the incessant push for improved productivity and quality, over the last decade there has been:

- a flattening of management structures which has increased skill requirements—'working with computers and the use of time management, quality systems and costing development is expected of every employee' (Gidion 2003, p.23).
- increased occupational multiskilling due to the requirement for 'cooperation between several occupational disciplines and product branches'. This has arisen partly from new technologies such as 'mechatronics', but also from the introduction of just-in-time systems and product-service packages which require greater cooperation between people working in manufacturing and a variety of service industries (Gidion 2003, pp.18, 24).

Other changes include growing public and private research and development expenditures which are accelerating the pace of technological change, and the further incorporation of computer systems into all manufacturing activities (Gidion 2003, p.18). Wider political and social changes affecting vocational education and training include rising general education levels, tougher environmental regulations and the integration of East and West Germany VET systems (Gidion 2003, p.1). In addition, the demography of the German manufacturing industry is such that by 2007 the owners of approximately 150 000 businesses in the craft trade sector will retire. This has placed great pressure on the acquisition of management skills by employers and employees who are now predominately craft-trained (Gidion 2003, p.18).

## Response from the German VET system

The German VET system is responding in a variety of ways to these challenges. Firstly, the Federal Ministry of Education and Research—'the guiding and co-ordinating ministry' for education and VET—closely monitors technological change in Germany. It publishes an annual review of the technological performance of Germany based on long-running surveys and specific research projects (Gidion 2003, p.29). It should also be noted that, compared with Australia, there is large-scale government support for technology diffusion and product development. For example, the Fraunhofer Institut has 80 research establishments and employs 13 000 people, the majority of whom are qualified scientists and engineers, and has annual revenue of more than one billion Euro. The institute undertakes research with a predominantly commercial and practical orientation, in fields such as communications, energy, microelectronics, manufacturing, transport and the environment.

Industry is also responding by significantly increasing its job training expenditure (Gidion 2003, p.25), and this on-the-job training appears to complement rather than substitute for formal off-the-job training. Increased investment in more directly work-related training is also occurring in existing off-the-job training. For example, the training of team leaders ('industrie meisters') was substantially reformed in 1997. A new teaching and learning system was introduced with an emphasis on creating learning processes 'that are concordant with the daily tasks of team leaders … The idea behind the new kind of training is that learning in a setting very similar to the working environment enhances learning processes' (Gidion 2003, p.21).

In a measure designed to attract more academically able students into apprenticeships and stimulate continuous qualification upgrading, the federal government and Lander are encouraging universities to improve the recognition of VET qualifications (Gidion 2003, pp.22–3). Currently only 4.6% of 'trainees in the craft trade sector … hold a university entrance certificate' (Gidion 2003, p.18).

Finally, the processes for changing existing apprenticeships and introducing new apprenticeships have recently been speeded up. Altering existing apprenticeships is to occur within a year and the introduction of new apprenticeships is to take no more than two years. 'The intensified work on training regulations over the last years has triggered a modernisation thrust for training occupations. Since 1999, for instance, 18 new occupations have been created and 55 existing training occupations have been updated' (Gidion 2003, p.28). One of these new apprenticeships was 'mechatronician' (combining mechanical, electrical and electronic craft skills). In 1999 the intake of mechatronicians was 5500.

In Germany, both the labour market for trade occupations and the education system are subject to a dense network of regulations. This network is controlled by multiple tiers of institutions, including federal and regional governments, and employee representatives. The system is the foundation for the 'high skills ecosystem' operating in Germany in which the supply of a large and high-quality VET workforce is supported by firms that make intensive use of these skills in the production of first-class, high value-added manufacturing products and services (Finegold & Soskice 1988). However, this system is under intense pressure due to global competition which is threatening the high-productivity, high-wage German production model.

# Key results of the surveys

A semi-structured survey of TAFE teachers, employers, and industry association representatives provided new data relating to the role of the VET sector in innovation. This chapter summarises these results.

## Survey of TAFE teachers

Eighteen respondents in TAFE were interviewed face to face in four manufacturing fields across the three eastern mainland states. The respondents were selected from the four program areas of food processing, metallurgy and foundry, computer-controlled machining, and communication systems.

## Strategies used to identify new technologies

These questions explored the external or internal sources used by TAFE staff to identify trends in new technologies related to their teaching duties.

### TAFE use of external sources for technical information

Table 2 shows that a broad range of organisations external to TAFE are used by TAFE staff as sources of technical information. The most commonly cited source of information identified by 17 of the teachers interviewed was 'with learners'. This is not surprising as respondents stated that 'learners' from industry frequently use the most modern equipment and are involved in complex production processes. Given this finding, it is unsurprising that 16 teachers identified the following as sources of technical information: leading private companies who are users of advanced technologies; client service and time spent in manufacturing plants; industry associations; and industry training advisory bodies. The main reason given for choosing the two industry bodies is that both organisations are involved in the development of training packages. Some respondents also identified private technology development and diffusion organisations such as the Welding Technology Institute of Australia as an industry association. This is because many private technology development organisations are affiliated with industry associations.

The relatively high number of teachers (12) identifying universities as a source of information needs to be qualified. Most of the respondents stated that information tended to flow from TAFE to universities. For example, TAFE was involved in the training of university engineering students or technical officers in the operation of computer numerical controlled (CNC) equipment, or took part in one-off university-led projects such as the solar car challenge. Typical comments regarding TAFE involvement in both cooperative research centres and universities are that universities 'do not see TAFE as part of the structure of technical change' or that 'TAFE is not always brought in [in] a timely way'. One respondent neatly summed up the perceived relationship between universities and TAFE: 'universities design, we maintain'.

The least commonly identified external sources of information are 'other' (with mostly ex-students and ex-TAFE teachers as sources), TAFE-commissioned external consultants, and cooperative research centres. Those identifying cooperative research centres typically commented that the flow of information between these centres and TAFE was limited. Few identified TAFE-commissioned

external consultants because these consultants are mostly used for curriculum development after the teachers have decided on course content. The low number of teachers who saw cooperative research centres as playing an information role is consistent with the findings of Ferrier, Trood and Whittingham (2003), who identified weak links between TAFE and these centres.

**Table 2: TAFE use of external sources for technical information**

| External organisation | Yes | No | Formal relations with external organisation | Informal relations with external organisation | Most important source of information* |
|---|---|---|---|---|---|
| Universities | 12 | 6 | 6 | 12 | 2(4) |
| Cooperative research centres | 4 | 14 | 9 | 9 | 2(1) |
| Industry associations | 16 | 2 | 11 | 7 | 1(3) |
| 'Leading-edge' private companies who are users of advanced technologies | 16 | 2 | 10 | 8 | 1(5) |
| 'Leading-edge' private companies who are producers/suppliers of advanced technology | 15 | 3 | 6 | 12 | 1(4) |
| Client service and time in plants | 16 | 2 | 11 | 7 | 1(1) |
| With shop floor | 15 | 3 | 10 | 8 | 1(3) |
| With management | 14 | 4 | 12 | 6 | 1(1) |
| With learners | 17 | 1 | 13 | 5 | 1(1), 2(1) |
| ITABs | 16 | 2 | 11 | 7 | |
| TAFE-commissioned external consultants | 7 | 11 | 18 | 0 | |
| Private VET providers | 12 | 6 | 7 | 11 | |
| Other (please specify) | 7 | 11 | 3 | 15 | 2(1) |

Notes: *Respondents identified an external organisation as being either the first or second most important source of information from the list of ten organisations. The number in brackets indicates the number of respondents who identified the particular external organisation as being an important source.

ITABs = industry training advisory bodies

While many external organisations are identified as sources of technical information, teachers clearly ranked leading-edge private firms who are users of advanced technologies as the most important source of such knowledge. This was closely followed by leading-edge firms who are producers/suppliers of advanced technologies. These results are consistent with the broader literature on the sources and diffusion of technical innovation (von Hippel 1988). The third most important sources of external information were the shop floor of companies with whom TAFE was involved, and industry associations.

There was considerable variation in the extent to which TAFE had formal relations with these external sources. There is no obvious link between the type of relationship the external source had with TAFE—whether it was formal or informal—and its level of importance.

## TAFE use of internal sources for technical information

Respondents were also asked about the use of internal sources of information on technical change (table 3). The most commonly identified internal sources, by a large margin, were website searches and journal circulation, with all respondents using these sources. Most respondents also identified these as the most important internal sources of information.

**Table 3: TAFE use of internal sources for technical information**

| Internal organisations | Yes | No | Most important source* |
|---|---|---|---|
| Internal TAFE research capacity | 11 | 7 | - |
| Within your college/institute | 5 | 13 | - |
| TAFE in other regions/ states | 16 | 2 | 2(2) |
| Professional development and training | 14 | 4 | 2 |
| Journal circulation | 18 | - | 1(5) |
| Website searches | 18 | - | 1(9) |

Note: *Respondents identified an external organisation as being either the first or second most important source of information from the list of ten organisations. The number in brackets indicates the number of respondents who identified the particular external organisation as being an important source.

One result does require clarification. There is an apparent discrepancy between the nearly two-thirds of respondents who identified internal TAFE research capacity as a source of information on new technologies, and the just over a quarter who identified resources within the college or institute as a source of information. This inconsistency is due to the fact that almost all those who stated that internal TAFE research capacity was important worked either in a central curricula/learning materials development unit, or in a dedicated centre designed for both teaching and promotion of technology. Very few other current teachers in TAFE identified internal TAFE research capacity as an important source of technical information.

# Impediments to maintaining the currency of technical capacity

Another significant finding is that only two of the teachers stated they were satisfied with TAFE's capacity to identify new technologies. Reasons for the majority of teachers being dissatisfied fall into three categories: lack of resources, structural changes in the operation of TAFE, and the introduction of competency-based training. This section, which deals with the impediments TAFE staff face in keeping up to date with technical innovation, is a composite drawn from a number of sections in the survey dealing with this issue.

## Inadequate resources

Lack of resources encompassed issues such as reduced teacher numbers and inadequate capital funding resulting in an inability to replace older equipment. One respondent indicated that, in their discipline, staff numbers had dropped from '30 to eight teachers in five years'. Another noted that 'materials science used to have ten teachers', whereas now it has just one part-time teacher. Such staff reductions have affected not only teachers but also technical officers who were involved in storeperson roles and the set-up, modification and maintenance of machinery used for teaching. The loss of these positions means that these tasks fall to remaining teachers to fit into their workload. Keeping up to date with technical innovation is particularly difficult where there is only one teacher in a discipline in an institute or state.

Reduced teacher numbers create problems in gaining release for participation in return-to-industry programs. Many of the respondents were also concerned at the apparent increased difficulty in gaining funding and approval to attend professional development training and TAFE conferences related to their disciplines. Some respondents commented on the fact that return-to-industry programs and professional development are 'self-initiated rather than programmatic' and 'depends on self-motivation rather than a structured approach'. In this case, the fact that participation in activities designed to maintain the currency of their knowledge is not compulsory is seen as a limiting factor. (This would not seem to apply in Queensland where two weeks a year of 'return-to-industry' leave is an award provision.)

Schofield (2002) observed the low level of investment in teacher professional development in Victorian TAFE, and found that the:

> … level of organisational resources applied to continuous professional development suggest a TAFE system under stress leading to inadequate maintenance and development of its workforce … total investment in structured TAFE workforce training and development for 2002 is estimated to be about 1.9% of GWS [gross wages and salaries] … Research suggest that 3–4% might be a minimum level of investment expected in a rapidly changing professional organisation such as TAFE. (Schofield 2002, p.34)

It should be noted, however, that the 2002 level of expenditure on professional development TAFE is nearly three times that of the level in 1996.

Apparently supporting these concerns regarding the adequacy of funding for TAFE, a recent Business Council of Australia report found that real (inflation adjusted) 'revenues of public VET providers showed no increase during the 1997 and 2001 period'. However, over the same period 'training hours increased by 25 per cent suggesting a sharp decrease in resources allocated per student' (Business Council of Australia 2004, p.44).

Reduced staff numbers was not the only issue that concerned teachers. They were also worried that, in a number of disciplines, it had been many years since full-time appointments had been made. In one state the last full-time appointments to the fitting and machining and electrical/ communications disciplines were 1989 and 1991 respectively. The result is an ageing TAFE workforce, where the age of teachers interviewed was early-to-mid-fifties. Many teachers noted that there was no succession planning, and upon their retirement much of the knowledge regarding technology and the process of teaching in their discipline would be lost. In addition, the lack of 'renewal' of teacher numbers meant that fewer teachers had recent direct employment experience in businesses using the latest technologies. The increased reliance over the same period on casual teaching staff introduced people into the system with more recent industry experience. However, it has also added a new management role to the remaining full-time teachers—that of managing the growing numbers of part-time and casual staff.[8] This was a new role that was not part of the full-time teachers' original 'job description', and gave them less time for other important parts of the job. It should also be noted that one study found that casual TAFE teachers receive only about one-quarter of the professional development of full-time staff (Schofield 2002, p.34). (In some states such as New South Wales, casual staff can work up to two-thirds of the teaching hours of their full-time colleagues.)

In the higher technology fields that are the subject of this study, respondents stated that higher salaries in industry for skills in demand meant that 'retaining staff can be a major problem'. On the other hand, it was also noted that the decision to leave industry and become a teacher was motivated by a number of factors, of which income was only one. Nevertheless, salary levels would seem to be an issue in attracting and maintaining teachers who have skills that are in demand.[9]

Some respondents claimed that difficulties in accessing current equipment for use in the classroom were due to the allocation of funding to courses, which is based on student numbers. This funding

[8] An analysis of trends in the Victorian TAFE workforce from 1993–98 found that the annual average level of full-time male employment amongst tenured teachers declined by 6.2% per anum. Employment of male sessional teachers increased by 13% per annum (Shah 2000, tables 4 and 7). Male teachers comprise the overwhelming majority of teachers in the manufacturing industries that are the subject of the current study. More recent data indicate that currently only 48% of Victorian TAFE teachers are in 'ongoing employment' and that 29% are aged 52 years or more. One-third of TAFE teachers will retire in the next three to four years (Victorian Learning and Employment Skills Commission 2002).

[9] These survey results are supported by the Victorian TAFE Association, which notes the difficulties in 'recruiting the best and brightest to TAFE in the future, especially in regional Victoria. Lack of rewards and incentives for staff, perceptions that pay levels are uncompetitive, the absence of robust succession planning and flat career structures, combined with limited career and professional development opportunities … will make it hard for TAFE to remain competitive and an employer of choice' (Victorian TAFE Association 2001, p.12).

system does not recognise that the fixed and variable costs of courses may differ substantially. (Fixed costs relate to capital equipment and variable to consumables—teacher costs per hour are the same, regardless of the course.) One fitting and machining teacher noted that his discipline is 'inherently expensive compared to courses such as hospitality and this makes his school unpopular with management'. One graphic example of the problems in maintaining the currency of equipment was provided in the case of non-destructive testing, which is used to measure the quality of welds. 'When the current NDT [non-destructive testing] x-ray machine dies the course will probably end'. This could represent a dilemma for industry because those engaged in non-destructive testing 'must do the TAFE course to be licensed in these NDT areas so [there is] a problem if [the] course is not supported'.

It is of some potential concern that several respondents gave examples of the increased dependence of courses on donated or discounted capital equipment and consumables from industry and equipment suppliers. In fact, many teachers seem to be active in soliciting such donations. One teacher in the advanced machining discipline noted, for example, 'that fluid power would not survive without various donations'. Companies whose students are undergoing training or who have had a longer-term relation with a teacher or college typically provide donations. Several respondents commented on the important role of the armed services in making donations of redundant equipment. Equipment suppliers provide discounts to TAFE as a means of getting their equipment known by industry and accepted as a standard. One teacher in telecommunications noted that 'Some companies will supply redundant or outdated equipment. Suppliers will discount [prices]. Both of these are very important and we need to reinforce the links'.

This apparent growing dependence on donated equipment or equipment supplied at a discounted price is a concern for a number of reasons. The quality of teaching could be compromised as students are exposed to equipment, consumables and software that may not be based on industry standards or be the best for teaching purposes, but are used because they are all the training provider can afford. Such dependence may even endanger the continuation of courses should these donations cease.

Reinforcing this concern, many teachers stated that donations were becoming more difficult to get as a result of the increased intensity of competition in industry. In addition, largely as a result of reduced staff numbers, there was less actual contact with industry. Some respondents commented on the reduction of activities, such as equipment exhibitions and demonstrations, that used to occur in colleges. These activities not only encouraged links with local firms, but also generated donations and discounts from equipment suppliers.

## Structural change in TAFE

Structural changes in the operation of TAFE are also seen as inhibiting the ability of teachers to maintain the currency of their technical knowledge. An important change over the last ten years is the removal or reduction in centralised TAFE agencies involved in information collection and/or the development of curricula and learning materials. This is claimed to have increased the burden of information collection and dissemination on individual TAFE teachers, and contributed to inefficiency in the resulting duplication of data collection and analysis. One TAFE teacher noted that the system 'needs dedicated persons who identify technologies and do research and professional development around these'. It is of interest that the NSW TAFE Manufacturing Division continues to maintain such a central unit, although with reduced staff numbers, and that teachers in other states commented positively on the unit and use its learning materials.

The other structural change criticised by respondents was the introduction of competition between colleges and institutes when bidding for public and private training contracts. Promoting competition between colleges and institutes—in order to conform with national competition

policies—provided a disincentive for colleges to share information on new technologies and associated teaching and learning systems.[10]

## Training packages

The 18 practitioners interviewed were highly critical of training packages, competency-based training and competency standard units. One respondent from the telecommunication disciplines summed up the general feeling: 'CSUs [competency standard units] are so general as to be of little value in technology transfer. Training packages rapidly date due to the speed of industry change'. In addition, the packages were criticised for their lack of theory, or inadequate emphasis on providing an understanding of production processes. In the discipline of materials science, it was stated that the 'training package does not have critical underpinning knowledge and is just used as a "tick sheet" for learning outcomes'. Such arguments have been expressed frequently over the years by various authors (see for example Misko 2001).

Further interviews were conducted with TAFE teachers, and these revealed three possible sources of their dissatisfaction with competency-based training. Under the former curriculum-based scheme, a specific numbers of hours per module were allocated—for example, in metal and electrical trades, to theory mathematics and practical hand skills. Each of these broad topics was addressed through set texts and assessed through common statewide written theory and practical examinations. However, under competency-based training there are no set hours for these broad topics and no set texts. Without more guidance than that provided in the training packages, some teachers feel uncertain about how to structure the training to ensure an appropriate balance between theory and practice.

It was also observed by one teacher that students, in general, are much more interested in acquiring practical skills than competence in theory and mathematics. From this teacher's perspective, it is simply much easier to teach practical skills.

Another reason given is that, in training packages, the teaching and assessment of the theoretical and practical competencies to be acquired by each student are related to the needs of the workplace in which each student is employed. This creates difficulties for the teacher in devising customised training and assessments. Where workplaces have different standards required of employees—related to precision, tolerances of work and complexity of production operations—teachers then feel they have to use different quality standards for assessing individuals across workplaces. In other words, teachers are reluctant to apply different quality standards for theoretical and practical competencies to individuals who are studying for the same level of qualification. Related to this is that the selection of modules and training packages for students is based on the needs of each workplace. Some teachers claimed the flexibility in such arrangements resulted in training which is too firm-specific and does not provide the breadth of knowledge to produce a worker with portable recognised skills for their industry.

These criticisms of competency-based training and training packages are obviously based on very limited data. However, they are not new: Cornford (2000) discusses similar concerns to those offered by the teachers surveyed. Amongst other matters, they are also the subject of the recently completed ANTA report *High level review of training packages: Moving on …* (Schofield & McDonald 2004). It should be noted that the employers and industry association respondents were nearly unanimous in rejecting the teachers' criticisms of training packages and competency-based training.

[10] Schofield (2002, p.22) echoes this argument. Writing of the Victorian TAFE system, she notes that the 'strong emphasis on internal competition in previous policy frameworks provided few incentives for the development of knowledge or work networks between TAFE entities. Despite this, TAFE institutes have voluntarily collaborated in some areas where collaboration rather than competition is perceived to yield mutual benefits'.

## Teacher qualifications

Teachers were also questioned about whether their qualifications were adequate to cope with introducing new technologies into courses. The majority of teachers did not regard the level and age of their qualifications as limiting TAFE from being able to teach these new technologies. (While six of the 18 teachers indicated qualifications were a problem, half of these qualified their response by indicating both yes and no to the question.) Overall, teachers agreed that although most were aged in their mid-fifties—and thus typically qualifications were acquired many years ago—they still managed to maintain the currency of their knowledge of new technologies.

One issue that became evident during the course of the interviews was that some, and possibly the majority, of teachers taught courses at an Australian Qualification Framework (AQF) level higher than that of their own technical qualifications. (For example, certificate-qualified teachers were responsible for diploma-level courses.) Anecdotal evidence suggests that many teachers in the manufacturing disciplines covered in this report have AQF III/IV-level technical qualifications. On the other hand, the teachers typically have education-related qualifications at a higher AQF level than their technical qualifications. This is an issue which deserves further research.

# Strategies used by teachers to redress impediments

In their interviews, teachers gave the impression that they are facing increasing barriers both to accessing new technical knowledge and introducing it into the classroom. Nevertheless, it is also the case that the large majority of respondents indicated their current qualifications and knowledge were not impeding their ability to introduce new technologies. In other words, while the respondents identified a variety of institutional barriers to identifying and introducing new technologies, they believed their own technical knowledge and teaching skills were not a barrier. The teachers used three strategies to maintain the currency of their own knowledge.

The first strategy was heavy reliance on the internet. This was used not only to identify new technologies—as displayed, for example, on equipment manufacturer/seller websites—but also to identify the latest teaching styles associated with new technologies. Several respondents noted, however, that this was not an ideal medium, as considerable background knowledge was required to separate 'marketing hype' from reality to identify trends in technology.

The second was to rely on informal college, intrastate and interstate networks of teachers in similar disciplines. For example, one college in Queensland was notable for the high level of cooperation between the fitting/machining and electrical trades disciplines. These teachers would pool the annual allowance provided to each individual for personal development to enable one teacher to attend an activity such as an interstate conference. In return, after attending the conference, the individual would provide training to the whole group. Another often-cited practice across all states was an informal division of labour in an institute or discipline, where individuals would specialise in maintaining the currency of the knowledge and skills in one field and share it with others. Some teachers also established their own websites for the purpose of sharing information amongst themselves. The intrastate and interstate informal networks seem to depend, in part, on the fact that teachers had spent a long time in the system and thus relied on networks established when more funding was available for travel and conferences. In this case, the need for such relationships has overcome impediments such as reduced funding for travel and increased competition between colleges which, the teachers claim, is corroding information-sharing.

Related to this second strategy is the networking undertaken with business to identify trends in technology use and to arrange student access to the latest equipment in the private sector. Concerns were also expressed about the viability of this strategy, given the reduction in staff numbers which seems to have reduced contact and information-sharing between TAFE teachers and industry.

The final strategy was to emphasise the teaching of theory or the underlying principles of production processes. Such principles can even be taught on redundant equipment, as described by

one teacher who uses a 1972 vintage ultrasonic device for non-destructive testing. One teacher in telecommunications stated that 'the critical issue is base principles or underpinning knowledge that allows students/teachers to move from product to product or system to system. This makes it possible for people to move with changes in technology'. The use of older or redundant equipment for teaching purposes creates a necessity to rely more on the imparting of general principles related to the production process.

Respondents were asked to suggest solutions to the problems they were facing in introducing and accessing new technologies. The most commonly identified solutions were more resources for equipment purchase and more staff, especially the recruitment of teachers with recent industry experience. More ready access to return-to-industry programs was also sought. Respondents also had a number of new ideas, such as TAFE and industry sharing the purchase/lease costs of modern equipment, which could then be used in a firm for production and at other times for teaching. Reducing competition between colleges would also improve information-sharing. Reinstating and/or expanding central agencies to collect, analyse and disseminate trends in new technologies and associated systems of learning were also suggested.

# Selection and acquisition of new technologies

This section deals with the methods employed by TAFE teachers when selecting new technologies for use in teaching. The respondents interpreted the question as applying to capital purchases—equipment such as welding machines and computer printers—but not to consumables, or materials which are used in the production process (for example, welding rods, lubricants, paper and gases). In the case of capital purchases, a tender process is typically used to acquire equipment or software.

## Use of formal technology selection methods

Fourteen of the 18 teachers indicated that formal written procedures were not required in selecting new technologies to be used in teaching. These procedures were defined as prescribed documentation for proposals to acquire new technologies using methods such as 'surveying industry to determine likely demand for training; evaluating technical superiority over competing technologies or formally calculating expected costs against expected revenues'. Two respondents indicated the question was not applicable to them and another two stated that they used formal procedures.

While the great majority of teachers indicated that prescribed formal procedures were not required for capital purchases, most of them used some 'formal' methods in evaluating technology acquisitions. The most important of these was to 'find out what is adopted in industry' or equivalently to ensure the prospective purchase is 'compatible' with industry's need. Another method mentioned by respondents was to ensure that the equipment generates 'enrolments', and is of interest to students. Most of the respondents also nominated consulting with other teachers to evaluate the merits of a particular purchase as an important step.

It is clear, however, that no formal system—in terms of prescribed methods for identifying and evaluating the relative merits of particular technologies—is generally employed. This is an issue which requires further investigation to determine if the introduction of a standardised formal method would improve the quality of capital purchases.

## Methods for acquiring technologies

In terms of acquiring or accessing new technologies for use in the classroom, it is clear that direct purchasing is highly favoured, with 15 respondents nominating this method (table 4). Cooperation with suppliers and/or users of equipment was identified by three-quarters of respondents as a means of acquiring or accessing new technologies. Earlier it was shown that suppliers and/or users of equipment were also identified as the most important external sources of information on new technologies. These sources were important for donations or discounted prices on new or

redundant equipment and consumables. They also provided on-site access to students/teachers to gain experience on the latest equipment. Grants in the form of special government funding programs such as 'infrastructure grants' were identified by a third of respondents, but most of these indicated that they were not available very often.

**Table 4: What are the main methods for acquiring/accessing new technologies?**

| Technology source | Yes | No | NA |
|---|---|---|---|
| Purchase/lease* | 15 | 3 | |
| Grant from external organisation | 6 | 9 | 3 |
| Cooperation with equipment suppliers/users | 14 | 2 | 2 |
| Other | 5 | 5 | 8 |

Notes: *Comments from teachers suggest leasing of capital equipment is not commonly used.
NA = not available

## Training the trainer

After technologies are acquired, a variety of means is used to bring teaching staff 'up to speed' on them (table 5). Fourteen of the 18 teachers nominated supplier-provided training and the development of learning materials associated with newly acquired technologies as the principal means for familiarising staff with recently acquired technologies. One teacher commented that 'the real learning comes from long-term practice and experiment'. Training from equipment suppliers was typically short-term, due to the prohibitive expense. Recruiting new staff to teach new technologies was identified by 11 respondents, although most of these indicated such appointments were usually part-time. Half the respondents identified existing users of the equipment in industry as sources of information on the new technology. No respondent indicated that universities or cooperative research centres were used to provide teaching staff with new information.

**Table 5: When new technologies are acquired, what are the principal means for bringing teaching staff up to speed on the technology?**

| | Yes | No | NA |
|---|---|---|---|
| Supplier-provided training | 14 | 1 | 3 |
| During the development of learning materials | 14 | 2 | 2 |
| Through existing users of the equipment (i.e. time in industry) | 9 | 6 | 3 |
| Other educational institutions (unis/CRCs) | | 16 | 2 |
| Internal training From TAFE resources | 7 | 9 | 2 |
| Recruit new staff | 11 | 5 | 2 |
| Other | | 6 | 12 |

Notes: NA = not available
CRCs = cooperative research centres

## Adapting new technology to teaching

There was no agreement over whether recently acquired technologies needed to be adapted or modified to the teaching environment. Nine respondents stated technologies require modification and seven claimed they do not. The remainder stated that the question was not applicable. One reason given for adaptation not being required is that 'technology is driven by international standards [so it] is not really practical to adapt or modify'. Another explanation is that new machines are ordered to the teachers' specifications and therefore do not require modification. The loss of technical officer positions over the years was seen as a constraint on the capacity of TAFE to modify equipment, as this had been a role performed under the supervision of teachers.

On the other hand, a stimulus for adaptation is that teachers 'often have to retro fit due to the age of the machines'. (Retro fitting entails changes to the hardware or software of older equipment

intended to add functions that are available on more modern machinery.) One teacher stated that adaptation 'is the story of life. If they did not have the skills to modify then they could not teach. All industrial systems get modified and all teachers do it—usually with no direction'. Another stimulus to modify plant/software was to better prepare students to meet the needs of prospective employers who use these technologies.

## Research and development

The issue of research and development activities in TAFE was also investigated, with seven of the 18 respondents saying they were involved in this area. For the purpose of this survey, research and development was defined as 'the development or novel application of technology'. However, more than half of the respondents cited curriculum development and associated activities as examples of their research and development experience. These responses were discounted, because curriculum development could have merely entailed the explanation of existing technologies, not the development of new technologies or their novel application. On this basis, three of the 18 teachers were involved in research and development. Even on this restricted definition, around one in six of the TAFE teachers interviewed was involved in the development or novel application of technologies.

Important avenues for research and development occur when teachers are in plants undertaking training and incidentally get involved in product and process improvements. Firms also approach TAFE teachers either formally or informally for product and process improvements. (These findings are consistent with the role of public VET providers identified in Rosenfeld [1998].) As would be expected, the teacher efforts in research and development are more focused on development—that is, the deployment or commercialisation of current technologies—than the research of new technologies. Examples of research and development included:

- 'A piano maker worked with teachers to build a specialist drilling machine for tension and angle of wire'.
- '3D [three-dimensional] drawing for cable sheaths for draglines [in open cut mines] on TAFE system'. In this instance TAFE engineering software was used by a teacher on a return-to-industry program to design equipment on an open cut mining machine.
- 'In the past [staff] did research and development from colleges, e.g. teachers in automotive got involved in a project to make a car go the furthest on a litre of fuel'.
- 'Assist in process problems when there is no resident metallurgist. Tubemakers found unexplained porosity in castings which was due to water leaking into bins'.
- 'Project [was] brought in by the university, e.g. particular metals for the solar car for TAFE to do the machining'.

The principal reason given by teachers for not having a higher level of participation in research and development is lack of resources. Several respondents expressed a desire to be more involved in this area. Typical responses included the following:

- 'No money, no time, no staff'.
- 'Have skilled staff but it has never been [the section's] brief … it is a double standard as they are told to get involved with industry but are given no resources to service this'.
- 'Too busy teaching and very little release time available compared to the past. Teachers have the skills to cope with a broad range of sophisticated materials and software'.
- 'Staff are more than capable of R&D [research and development] work (e.g. iris scan) but not without facilities, time and capital'.
- 'We fail to attract R&D money because TAFE is not seen as an R&D facility … outside TAFE and even by some inside TAFE because resources are solely targeted at training delivery'.

As a group, the respondents saw definite advantages in being involved in research and development, as exemplified in the following comment. 'Obviously students would be more exposed to the cutting edge of the industry if we did R&D in a more structured way.'

These findings regarding the research and development activities of teachers raise potentially important policy issues. For example, currently TAFE is specifically excluded from ABS surveys of research and development in public higher education institutions (ABS 2000). Secondly, the role of TAFE in developing and diffusing new technologies is not widely recognised in state and federal government innovation strategies.

An important observation made by the respondents is that some small and medium-sized businesses base their capital purchases on equipment available in TAFE. This is to ensure that their employees receive training at TAFE which directly matches their production processes. Small and medium-sized businesses also use TAFE teachers as advisors on technology purchases. Although not strictly research and development activities, these observations point to the many ways in which TAFE is involved, directly or indirectly, in technology diffusion.

The role of TAFE teachers in product and process improvement is a potentially important topic which deserves further investigation.

# Survey of employers

A small survey of eight innovation-intensive manufacturing firms was undertaken. The firms were in the food processing, foundry, advanced metals machining and telecommunications industries, with all receiving training from TAFE, as well as from other providers. Respondents included training managers, production managers and human resource managers. The training covered process operators, apprentice and post-trade skills. The smallest firm had 20 employees, while the largest over 3500 employees in Australia. Six of the eight firms were either Australian or overseas-headquartered multinationals. This reflects the key role of multinational corporations in innovation, and the comparatively high share of overseas ownership of innovation-intensive industries in Australia (Toner 2004).

The purpose of the interviews was to gain an industry perspective on some of the key issues in assessing how well TAFE maintains the currency of its human and physical resources.

## Adequacy of TAFE equipment

The private companies interviewed had varying ideas about whether TAFE equipment was current enough to meet their technology teaching needs. Three of the eight companies were satisfied with TAFE's equipment, one company was dissatisfied and the remaining four firms were moderately satisfied.[11] Importantly, two of the three satisfied firms had particularly close partnerships with TAFE and provided equipment and training opportunities for TAFE teachers to maintain their skills. These two firms were in the telecommunications industry and have formed close alliances with particular TAFE colleges, where their technician-level training is linked to on-the-job training provided within each firm.[12] Toner et al. (2004a) also reveal that close consultation between firms and TAFE promoted industry satisfaction with vocational training providers.

Companies provided several reasons for being moderately satisfied with TAFE equipment. One company revealed that it had advanced, although generally available, metal machining plant which would be too expensive for TAFE to provide. Thus, while the TAFE equipment was comparatively dated, it was still 'compatible' because the older TAFE equipment and the classroom theory

[11] The questions regarding satisfaction were bivariate (yes or no). Moderate satisfaction is defined as those instances when respondents chose both yes and no, indicating they were ambivalent about their satisfaction.

[12] Further information on this model of cooperation is available from the Optus Cadet Program case study outlined in Toner et al. (2004b, p.29).

provided students with skills in the use of manual plant (for example, hand-cutting materials) and understanding production processes. These manual skills, although not used on the firm's computer-controlled machinery, were essential to the students achieving competence on the firm's more advanced equipment. The TAFE classroom experience gave the students vital skills, such as 'a feeling for and understanding of cutting speeds and type of material' which could not be gained on the firm's computer-controlled equipment. Without this understanding, firms believed that expensive computer-controlled equipment could actually be damaged. (This is similar to the argument of Jacobs [2003], that competence in manual processes is essential for undertaking equivalent computerised processes. Jacobs used the example of robot welding.)

One firm involved in manufacturing optical fibre had proprietary technologies which were not available elsewhere, and so had to provide this training in-house. A food-processing firm regarded training provided on its own equipment as the most economical way of familiarising trainees with company requirements. Another firm involved in aircraft maintenance was eager for TAFE to upgrade the aircraft it used for training, because within the next three to four years the models would be redundant. However, the respondent was concerned about how TAFE would be able to afford such an outlay.

The one company which was dissatisfied with TAFE's equipment was particularly concerned about both its currency and the decline in the number of colleges providing this training. There was a strong likelihood that the remaining training site in New South Wales would close and the firm would be forced to send their apprentices to Victoria on block release (where students are away from work for weeks at a time attending distant colleges).

These results support the claims of TAFE teachers that there is some basis for concern regarding TAFE's ability to meet the teaching needs of more innovation-intensive industries, particularly in terms of maintaining up-to-date equipment.

## Adequacy of teacher qualifications and training packages

A much higher proportion of firms was satisfied with TAFE teacher qualifications and theoretical and practical skills. Six firms expressed satisfaction, one expressed moderate satisfaction and another indicated that they were dissatisfied. This last firm was in the aircraft maintenance industry and also revealed that they were only moderately satisfied with TAFE equipment. Staff had particular concerns about the teaching skills of TAFE part-time teachers, believing that TAFE could only attract lesser skilled applicants to teaching positions in aircraft maintenance, given that industry offered much better pay and conditions.

Generally, however, these results are consistent with those of the survey of TAFE teachers, who regard their current qualifications and knowledge as adequate to the task.

Seven of the eight firms were satisfied with training packages in terms of their ability to keep up to date with new technologies. One firm was moderately satisfied. Although they were satisfied, however, several of the firms qualified their support. The aircraft maintenance firm believed that the packages were making a 'reasonable effort', but 'regulatory changes do make it difficult for training packages to keep up'. The foundry respondent noted that there is 'no alternative' to the packages and a food-processing firm said they were 'improving'. These results stand in contrast to the opinions of the TAFE teachers, who were highly critical of training packages. This strong difference in perception of the value of training packages is an interesting finding and worthy of further study.

## Employer use of TAFE research and development

None of the firms consulted with TAFE on the availability of training prior to acquiring new equipment or introducing a new product. The reasons given for this lack of consultation were that equipment vendors supply the necessary training, or equipment and/or new products are developed in-house and so firms provide their own training. Hence, for these firms, TAFE did not have a role to play.

However, one firm used TAFE facilities and/or personnel in a research and development role for developing new products or production processes. This firm was in the telecommunications industry and described 'a tight partnership' where TAFE teachers and technicians in the company 'bounce ideas off each other' in terms of developing and introducing new telecommunications hardware and associated software. (It should be noted that the question specifically excluded any teaching role TAFE staff may have regarding the new product or process. One company believed that TAFE played a role in their research and development activities because it provided support when the firm introduced a new customer service program for their staff. However, this example was discounted as not fitting the strict definition of technologically new or improved product or process.)

This response gives limited support to the view of TAFE teachers that, on occasion, they are involved in assisting firms to develop technologically new products and processes.

### Summary of employer survey

Overall, there is a reasonable correspondence between the perceptions of the TAFE teachers and those of the innovation-intensive firms regarding the role of, and impediments to, TAFE participation in fostering technical innovation. The main exception was the disagreement regarding the effectiveness of training packages keeping up to date with technical change and as a suitable tool for providing a theoretical understanding of production processes.

## Survey of industry associations

Four education and training officers from a major industry association with coverage of the innovation-intensive manufacturing industries were also interviewed. The survey included most of the questions provided to the companies, as well as questions which sought an industry association perspective on the principal findings from the survey of TAFE teachers.

All four officers expressed dissatisfaction with TAFE's ability to maintain up-to-date equipment. This result is consistent with the results of the survey of TAFE teachers and employers. One respondent noted that 'they understand how difficult it is as a public institution to find the dollars to keep up'. Another noted both the level of funding provided by the state government, and the fact that government encourages the purchase of equipment rather than leasing. Leasing would allow a faster turnaround of equipment and allow TAFE to access more recent models. The respondent suggested that the requirement for capital funds to be fully expended over a fiscal year precluded longer-term financial commitments such as those involved in leasing. As with the survey of teachers, the industry association officers suggested that 'TAFE could buy time on the latest equipment in private industry'. Another officer recommended that TAFE machinery 'should not be bolted to the floor' but transported between colleges as it was needed.

Three of the four officers were dissatisfied with the level of qualifications and theoretical and practical skills of the teachers. The officer who was satisfied commented that they 'were always impressed by the professionalism of TAFE teachers'. A reason for dissatisfaction was the difficulty TAFE teachers have in making the transition 'from the classroom to the workplace' which is required for competency-based training. Two respondents raised an issue that was highlighted earlier—that the technical qualifications of TAFE teachers are generally at a lower level than their education-related qualifications.

Three of the four officers were moderately satisfied with training packages, noting the 'long gestation period' between conception and 'supply to the market' which was seen as a barrier to maintaining their technical currency. The remaining officer, however, was satisfied with training packages.

The officers were also asked to comment on the principal findings from the TAFE teacher interviews. There was general support for the idea that reduced TAFE staff numbers adversely affected the capacity of teachers to participate in return-to-industry programs and establish networks with firms. One officer noted that reduced employment in TAFE 'mirrors the problems

industry has in cutting staff'. Under pressure to reduce costs, industry has cut employment to the level where it is not possible to release employees from production to participate in training (Australian Centre for Industrial Relations, Research and Training 2002, pp.33–8).

Another officer linked reduced teacher employment to reduced availability of courses. Courses which were previously available in multiple colleges have been 'rationalised' so that they can only be taken at one or two colleges, which has increased the need for students to undertake them on block release. Block release increases the cost and inconvenience of training and was seen as a disincentive for employers to invest in training.

There was general agreement that reduced student numbers were making it more difficult to maintain the currency of TAFE equipment, given the link between funding and student numbers. One officer noted that skill shortages in manufacturing had reached a point where, especially with the prospective retirement of a large proportion of skilled labour, industry was now prepared to invest more in training. Another officer argued that TAFE teachers should be more diligent in 'growing the training market' by more active marketing and involvement with industry.

Officers were divided regarding the teachers' argument that the removal or reduction of central agencies which disseminated information about new technologies had produced inefficiencies by leaving this job to individual teachers, with a resulting duplication of effort. Two officers agreed, while the other two regarded it as the responsibility of the teachers to be more active in seeking out ideas from agencies, such as industry training advisory bodies.

Three of the officers expressed concern at the adverse effects of increased competition between colleges for training contracts, and agreed that increased competition had created disincentives to the sharing of knowledge and resources. One officer stated that problems were 'definitely' occurring and had observed the 'duplicating of resources' due to reduced cooperation between colleges. Another officer commented that it was a particular problem in Victoria and they would 'hate to see it happen in NSW'. The officer who disagreed with the claim argued that it was up to the colleges to make a clear distinction between situations in which they needed to compete, or ones in which they could foster cooperation.

Finally, there was no support for the teachers' contention that competency-based training reduced their ability to teach the underlying theory of production processes. One regarded the teachers' position as 'nonsense', and another argued that as 'teaching professionals' it was their 'responsibility to achieve outcomes' specified in the training packages, including the acquisition of competence in the theory underlying prescribed tasks.

## Summary of industry association survey

Overall, there is a reasonable degree of correspondence between the views of the industry association training and education officers, and the teachers. All had similar attitudes regarding the key topics discussed—dissatisfaction with the TAFE system's ability to keep its equipment up to date, the difficulties teachers have in accessing return-to-industry programs, and the adverse effects of reduced student numbers and increased competition between colleges. However, by contrast with the teachers, the industry association representatives were relatively positive about training packages and supportive of competency-based training. Finally, three of the four industry association representatives expressed concern about the level of TAFE teacher qualifications, by comparison with the teachers themselves who felt they were adequately qualified.

# Conclusion

This conclusion seeks to provide the most important findings of the study by using the framework of the original research questions. It is important to note that conclusions relating to the Australian TAFE system apply only to selected fields of study in manufacturing-related activities. It must also be emphasised that the results are tentative, due to the small survey sample and the fact that it is the first such study undertaken in Australia. The conclusion also contains a number of suggestions for further research or policy development.

*What are the key national and selected international patterns and institutional bases for knowledge diffusion in the VET sector?*

International literature and the commissioned studies from Germany and the United States point to an increasingly important role for VET institutions in 'technology deployment', or the diffusion of new technical knowledge. Clearly, VET institutions have always had such a role, but changes over the last two decades have given this role greater prominence in public policy. These changes include an increase in a number of important areas: pace of technical change; knowledge intensity of production; and share of knowledge-intensive goods and services in exports. The lift in the knowledge-intensity of production is evident in the increase in the ratio of research and development expenditures to net industry output, and the rising share of more highly qualified employees in the workforce. Another important factor is the shift in public policy towards support for both knowledge generation (through public and private research and development) and the deployment of technical know-how, especially to small and medium-sized enterprises through technical colleges. Technical colleges are also a vital element in the suite of programs and policies used by local and national governments to attract inward investment.

In the United States, Germany and Australia there appear to be common difficulties in maintaining the currency of knowledge and equipment within public technical institutions. Problems relate to an ageing teaching workforce, maintaining leading-edge equipment which is very costly and quickly becomes redundant, and the re-orientation of teaching from general industry-specific skills delivered in the classroom towards more customised and firm-specific training. Other difficulties include the declining academic ability of students and the gap in pay and conditions for skills in demand between those obtained in the VET sector and those in private industry.

International comparisons also reveal that the Australian Government is less aware of the key role which technical colleges can play in the technology diffusion process and innovation. This is indicated by the small amount of funding given to Australian technical colleges from government technology diffusion programs. In addition, there is little integration of technical colleges with broader industry policies. However, this study reveals that for TAFE to assume a more prominent role in technology diffusion it would need additional resources in terms of teacher numbers, upgraded equipment and possibly upgraded teacher technical qualifications.

*What are the formal and informal institutions and processes used by TAFE to identify key technological innovations? What are the institutions and methods used to identify the impact on and implications for TAFE of these new technologies? What methods and criteria are used to select amongst competing technologies and how are priorities for acquisition set? How are these innovations sourced and acquired? What are the institutional arrangements and methods used to adapt TAFE operations and skills to these new technologies? How are the new technologies adapted to TAFE operations?*

Teachers use a wide range of sources to identify new technologies. The most commonly used and important external sources are leading-edge private users or producers/suppliers of advanced technologies, industry associations, and time spent with the learners themselves and in plants. The most commonly cited and important internal sources are websites and journal circulation. Sharing information and networking with other TAFE colleges and undertaking professional development are also important. This study confirms the finding of earlier Australian studies that the link between TAFE and universities/cooperative research centres needs to be strengthened.

Major technology acquisitions are typically obtained by tender in accordance with state treasury capital purchase guidelines. However, just over three-quarters of the teachers indicated that formal written procedures to justify the acquisition of new technologies were not required. These procedures were defined as surveying industry to determine likely demand for training, comparing technologies to ascertain which ones are superior, or formally calculating costs of acquisition against expected revenues. While some teachers indicated some of these procedures were used in preparing written requests for technology acquisitions, most reported that they were not mandatory. It is clear that no formal system, in terms of prescribed methods for identifying and evaluating the relative methods of particular technologies, is generally employed in TAFE in the purchase of new capital equipment. This is an issue which should be further investigated to determine if the introduction of a standardised formal method would improve the quality of capital purchases.

The great majority of teachers (15 out of 18) indicated that, of the various methods for acquiring new technologies, direct purchasing was used most often. Three-quarters said that they cooperated with equipment suppliers and or/users in acquiring new equipment. This cooperation took the form of donations or price reductions by equipment suppliers in return for having their goods widely exposed to industry through their use in TAFE. In fact, some courses seemed to be reliant on donations of both capital equipment and consumables, and teachers gave the impression that this dependence had increased over time.

Teachers revealed a number of strategies for learning how to use new technologies. These included training from equipment suppliers, and becoming familiar internally at TAFE during the development of learning materials for the new technology. Other strategies involved recruiting new staff with greater technical expertise, and seeking advice from industry or through participating in return-to-industry programs.

Teachers had completely varying ideas over whether newly acquired technologies required modification to the teaching environment. (Interestingly, there was not even consensus amongst teachers engaged in the same field of study.)

*Are the institutions and processes used to identify, select, acquire, and adapt innovations adequate? Are the resources devoted to the task adequate?*

The report concludes that the institutions and processes used to identify and maintain the currency of equipment and teacher knowledge are inadequate.

Only two of the 18 teachers stated that they were satisfied with their capacity and that of the wider TAFE system to identify new technologies. Widespread concerns were also expressed regarding the age of equipment used for teaching. However, teachers did employ three strategies to overcome barriers to maintaining the currency of their knowledge and skills. These strategies included a heavy reliance on the internet, sharing information through networks with other teachers and industry, and trying to ensure that they taught the principles underlying production processes. This emphasis on theory was an attempt to compensate for older equipment, as well as a commitment by teachers to providing generic, portable skills as opposed to firm-specific training.

It is notable that companies which were satisfied with the currency of TAFE equipment and teacher skills had especially close relations with TAFE. These firms supplied equipment, contributed to the upskilling of teachers, and had active involvement in the design of course content. This confirms

the results of earlier research showing the positive association between the level of satisfaction with vocational education and training by companies and the amount of cooperation and assistance they provided to the sector.

TAFE's ability to maintain the currency of its equipment drew criticism from both groups, with the majority of employers interviewed moderately dissatisfied, and all the industry association representatives dissatisfied. Teacher skills and qualifications gained a mixed reaction; most employers were satisfied, but most employer association representatives were not. Information was also provided indicating that teachers conducted courses at a higher AQF level than their own technical qualifications.

*What are the impediments to improving the institutions and processes to identify, select, acquire, and adapt innovations?*

A number of impediments was identified to maintaining the currency of TAFE teacher skills and equipment.

The most important factor was a lack of resources. This encompassed significantly reduced staff numbers and the inability to replace older equipment. Reduced staff numbers and low recruitment rates have resulted in a workforce where the age of the teachers surveyed was in the early-to-mid-fifties. In turn, this means that fewer full-time teachers have had recent direct employment in industry. Increased reliance on part-time and casual teachers may redress this problem, but it introduces other concerns such as full-time teachers having the additional responsibility of managing them. Reduced teacher numbers also increase the difficulty in gaining release for professional development and return-to-industry programs. The loss of technical officer positions in colleges was also claimed to have shifted additional duties to remaining teachers and to have reduced the capacity for modification and maintenance of equipment and software. Reduced teacher numbers have also affected the capacity to network with industry and conduct activities, such as equipment exhibitions and demonstrations in colleges, which strengthened links with both local firms and equipment suppliers.

Another significant issue was the abolition or reduction in central agencies, which collected and disseminated information on new technologies and developed learning materials for recently acquired technologies. Currently, teachers undertake this information collection and assessment function themselves, as individuals or groups, and those in Victoria and Queensland reported that they receive no external support. They perceive this as inefficient because it leads to a duplication of collection and analysis, a view supported by half of the industry association respondents. Teachers in Queensland and Victoria also rely on resources produced by the NSW Manufacturing Education Services Division.

This problem is exacerbated by the introduction of intrastate and interstate competition between colleges over the last decade. Teachers argued that this sense of competition has been a disincentive to the sharing of information and resources between colleges. This proposition was supported by three of the industry association respondents.

A consistent theme in the international literature is the decline in the academic ability of students entering the public VET sector, largely as a result of the expansion in university places and adverse perceptions about employment in manufacturing. While not the subject of this study, other research points to it being a restraint on the growth of student numbers (Toner 2003).

Finally, and most controversially, teachers criticised both training packages and competency-based training. Training packages were perceived as not being up to date with the latest technical developments, while competency-based training was seen to give insufficient priority to the principles underlying production processes. By contrast, employers and industry association representatives were overwhelmingly satisfied or moderately satisfied with training packages and competency-based training.

*How can these impediments be efficiently redressed?*

The most obvious solution to many of these problems is the provision of greater resources to the VET sector. This would include hiring more teachers, and providing greater access to professional development and return-to-industry programs. Salaries and conditions in TAFE may require examination and upgrading to attract more highly skilled applicants from industry who are in high demand.

It is not within the scope of this study to examine potential sources for funding this increase in resources. However, if the TAFE sector—or at least parts of the sector that clearly service innovation-intensive industries—were to be formally included in national innovation policy, this may result in additional sources of funding becoming available that are currently excluded from the sector.

Teachers and industry association representatives suggested that TAFE leases rather than purchase equipment to overcome problems with its currency. This could also allow new technologies to be turned around at a faster rate. Teachers and industry association representatives suggested that TAFE could buy or lease teaching time on equipment in industry, by working in partnership with firms to lease/buy equipment which could be used for both teaching and production.

The prospective retirement of older teachers in the short-to-medium term creates a unique opportunity to recruit people with more recent industry experience, some of whom should have higher-level technical qualifications. (At the same time, the loss of a large group with decades of teaching experience and industry networks will need to be managed carefully.)

As found in this research, and suggested in other studies, there is scope for increased cooperation with industry to upgrade TAFE equipment and teacher skills. Two companies in the telecommunication industry in this study made large contributions in this way. It should be recognised, however, that both of these firms were very large multinationals with the internal resources to make these donations and develop a relationship with TAFE. Other firms may not have the internal resources to make such commitments, even though they have substantial training requirements.

Strong disagreement was evident between the views of teachers, and those of firms and industry association representatives, regarding the effects of training packages and competency-based training. However, in the recent ANTA review of training packages, Schofield and McDonald (2004) would seem to have established some common ground between these two views. The review endorsed many of the teachers' criticisms, but did not suggest a way forward other than seeking to ensure that training packages included an adequate amount of theory and general principles.

Finally, the benefits of enhanced competition within TAFE in terms of increased efficiency and flexibility must be set against what appear to be costs in terms of reduced sharing of information and resources. It is important for institutes to look at ways of overcoming these negative effects of competition, and learn to distinguish between situations in which they need to compete, or ones where they can learn from and cooperate with one another.

*How well do state-based training intermediaries establish networks with knowledge producers in other states and coordinate knowledge diffusion with training intermediaries in other states?*

As noted above, the teachers and most of the industry association representatives expressed concern over the adverse effects of increased competition between colleges and institutes on the sharing of resources and information. (Similar observations were made in the international context by Rosenfeld 1998.) Teachers also expressed concern over reduced funding for intrastate and interstate travel, and for conference attendance.

This study finds that there is considerable scope for institutes and colleges to improve interstate and intrastate networks and the sharing of knowledge and ideas.

*To what extent should TAFE be a leader rather than a follower in the introduction of innovation?*

Under current resourcing it is not feasible for TAFE to be a leader in terms of providing technical training at a level equal to that of the most technically advanced industries. In addition, in some manufacturing industries the current and potential size of the market for higher-level VET training may be so small that it would not justify the public investment. Moreover, given that only a small proportion of Australian manufacturing firms will ever be at the 'leading edge' of technology, TAFE must continue to cater for a broad range of training needs and levels. Fundamentally, the answer to the question as to whether TAFE will be a leader or a follower in the introduction of technical innovation will be determined by the kind of role TAFE is given within the Australian innovation policy framework. Currently TAFE has, at best, a marginal role in this policy framework, although in practice it has a central role as a technology intermediary for intermediate skills.

# Future directions

The report recommends a number of ideas for further research and policy development:

- Government and policy-makers need to recognise the important role played by the VET sector in product and process innovation and technology diffusion. This role is especially vital for 'small and medium sized employers, whose requirements for technology and innovation [are] something less than leading-edge research and who … [lack] the capacities and connections to effectively adapt already commercially available technologies and proven innovations' (Rosenfeld 1998, p.2). For this recognition to occur, the public VET system in Australia must be integrated into national innovation policy and technology diffusion programs and Australian Bureau of Statistics data collections on innovation and research and development.
- As recommended by Ferrier, Trood and Whittingham (2003, p.43), the VET system should be able to monitor technology trends and undertake analysis of the effects of innovation on vocational education and training. The loss or reduction in state-based central agencies whose job it was to monitor and disseminate this information has weakened the VET system.
- National data on the VET system are lacking in many areas, thus making research on the topic very difficult. For example, there are no national standardised disaggregated time series data on fields of study relating to TAFE teacher employment, teacher qualifications, or capital expenditure and capital depreciation. There are also no data or benchmarks for determining the currency of factories and equipment or minimum standards on how well they meet the current technical requirements of industry. Without data such as these, it is not possible to accurately monitor trends in resource allocation within the TAFE system.
- It is clear that TAFE has no formal system—in terms of prescribed methods for identifying and evaluating the relative merits of particular technologies—when purchasing new capital equipment. Further research would be useful to determine whether the introduction of a standardised formal method improves the quality of capital purchases.
- Industry association representatives revealed that some teachers in manufacturing disciplines conduct courses at a higher AQF level than their own technical qualifications. This may have issues for their understanding of the subject matter.
- Respondents suggested a variety of strategies to improve the currency of equipment available to TAFE for teaching purposes. They include leasing, 'buying time' on equipment which is available in industry, and sharing costs and forming training alliances with industry.
- It appears that intrastate and interstate competition between colleges and institutes in bidding for public and private training contracts has made colleges unwilling to share information and resources. This could also intensify other problems which are occurring due to declining teacher numbers, redundant equipment and closure of central information agencies.

- ✧ Teachers had opposing views from those of firms and industry association representatives when asked about the usefulness of training packages and competency-based training as tools for technology deployment. There is, therefore, a fundamental split regarding the merits of training packages and competency-based training between those who deliver this training, and those who receive the training and/or have a major input into its design.

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# Appendices

## 1 Questionnaire for TAFE teachers

**It is important to note that no organisations or individuals will be identified in the final report and all data will be aggregated to ensure confidentiality.**

1. Identifying New Technologies

From the list of organisations **external** to your TAFE could you please indicate if they are a source of information on new technologies and the key types of information on new technologies you gain from these external organisations? Could you also please indicate whether your relationship with these organisations is formal or informal? (By formal we mean there are regular, planned meetings where issues relating to new technologies and training are discussed. Informal relations are those where contact is made with an external organisation only, or mostly, when you have particular issues or questions to discuss).

| | **External Organisations** | Y | N | Types of Information | Formal/ Informal | Most Important Source (Can state more than one) |
|---|---|---|---|---|---|---|
| 1.1 | Universities | | | | | |
| 1.2 | Cooperative research centres | | | | | |
| 1.3 | Industry associations | | | | | |
| 1.4 | "Leading edge" private companies who are users of advanced technologies | | | | | |
| 1.5 | "Leading edge" private companies who are producers/suppliers of advanced technologies | | | | | |
| 1.6 | Client service and time in plants | | | | | |
| *1.6.1* | *With shop floor* | | | | | |
| *1.6.2* | *With management* | | | | | |
| 1.7 | ITABs | | | | | |
| 1.8 | TAFE commissioned external consultants | | | | | |
| 1.9 | Private VET providers | | | | | |
| 1.10 | Other (please specify) | | | | | |

2. Could you please indicate if you use the following **internal** means (i.e. within your TAFE) to identify new technologies. Could you please indicate the key types of information on new technologies you gain from these **internal** organisations?

| | **Internal Organisations** | Y | **N** | Types of Information | Most Important Source (Can state more than one) |
|---|---|---|---|---|---|
| 2.1 | Internal TAFE research capacity | | | | |
| 2.1.1 | If yes, please describe | | | | |
| 2.2 | Within your College/Institute | | | | |
| 2.3 | TAFE in other regions/ states | | | | |
| 2.3 | Professional development & training | | | | |
| 2.4 | Journal circulation | | | | |
| 2.5 | Web site searches | | | | |
| 2.6 | Other (please describe) | | | | |

3. Which of the above **internal** organisations are the most important to you in identifying new technologies that are or should be part of your curricula?
4. Are you satisfied with the **external** and **internal** capacity to identify new technologies?
5. How could this capacity be improved? (For example, more co-operation across TAFE nationally).

### 3. Selection of New Technologies

The following questions relate to how you select new technologies that should be part of your curricula. In other words, having identified some new technologies how do you decide that it should be introduced to your TAFE or rejected.

| | | |
|---|---|---|
| 3.1 | Are there formal, written procedures required to be used in selecting new technologies? For example these formal procedures may entail surveying industry to determine likely demand for training; evaluating technical superiority over competing technologies; or formally calculating expected costs against expected revenues? If Yes please describe. [If No, go to 3.2] | |
| 3.2 | Or is the process of selection more informal, and varies from technology to technology? | |
| 3.3 | What informal methods are used? | |
| 3.4 | Are current teacher qualifications and knowledge a restraint on the capacity to introduce new technologies? | |
| 3.5 | If yes, why? | |
| 3.6 | How could this restraint be lifted? | |
| 3.7 | Are there any other restraints on your capacity to introduce new technologies? If yes, please describe | |
| 3.8 | How could these restraints be lifted? | |

## 4. Acquisition of New Technologies

4.1 What are the main methods for acquiring/accessing new technologies that should be part of your curricula?

| | | |
|---|---|---|
| 4.1.1 | Purchase/Lease | |
| 4.1.2 | Grant from external organisation | |
| 4.1.3 | Co-operation with suppliers or users for your teachers/students to have on-site access to their equipment | |
| 4.1.4 | Other (please specify) | |

4.2 When new technologies are acquired what are the principal means for bringing teaching staff up to speed on the technology?

| | **Staff Training Method** | |
|---|---|---|
| 4.2.1 | Supplier provided training | |
| 4.2.2 | During the development of learning materials | |
| 4.2.3 | Through existing users i.e. Time in plant | |
| 4.2.4 | Other educational institutions such as Universities or cooperative research centres | |
| 4.2.5 | Internal training from TAFE resources | |
| 4.2.6 | Recruiting new staff who have the skills (temp. or permanent) | |
| 4.2.7 | Other (please specify) | |

4.3 These questions relate to the modification/adaptation of new technologies acquired by your TAFE to meet TAFE's needs.

| | **Do you ever adapt/modify the technologies to the needs of:** | |
|---|---|---|
| 4.3.1 | Your teaching environment or curriculum. (Yes/No. If No, go to<br>Q. 4.3.3) If Yes, please give an example. Why was the modification/<br>adaptation undertaken?<br>Who undertook the modification? | |
| 4.3.2 | The likely employers of those trained? If Yes, please give an example. Who undertook the modification? | |

## 5. Research & Development & TAFE

| | **Type of R&D Activity** | Y | N | Type of Activity |
|---|---|---|---|---|
| 5.1 | Does your division/department undertake any R&D<br>(Developing or novel applications of technology) (Yes/No, If No, go to Q. 5.4) | | | |
| 5.2 | Is this R&D done on a one-off, project basis? Yes/No, If No, go to Q. 5.3.<br>Who initiated it?<br>How is it funded?<br>Is it internal or done with external bodies? | | | |
| 5.3 | Or is their centre with dedicated staff.<br>Where is it located?<br>Who initiated it?<br>How is it funded? | | | |
| 5.4 | If there is no R&D, why not? | | | |
| 5.4.1 | Not required | | | |
| 5.4.2 | Lack of resources, skilled staff etc? | | | |
| 5.5 | If your Department/<br>Division does undertake R&D, what are the benefits/disadvantages to your teachers, students & TAFE? | | | |
| 5.6 | Are there any restraints on these R&D activities? (Lack of resources, skilled staff) | | | |

# 2 Questionnaire for survey of companies

These questions relate to the more advanced production process involving TAFE trained employees.

1. **Are you satisfied with how up to date TAFE equipment is for meeting your technology teaching needs? Yes/No**

   1.1 If not why not?

   1.2 What can be done to improve the technical standards of equipment?

2. **Are you satisfied with the level of qualifications and theoretical and practical skills of TAFE teachers? Yes/No**

   2.1 If not why not?

   2.2 What can be done to improve the level of skills of TAFE teachers?

3. **Are you satisfied with Training Packages in terms of keeping up to date with new technologies? Yes/No**

   3.1 If not why not?

   3.2 What can be done to improve the Training Packages?

4. **When your company considers acquiring new equipment or introducing a new product do you consult with TAFE on the availability of training for the new technology/product? Yes/No**

   4.1 If yes, could you please provide and example of this consultation?

5. **Does your company use TAFE facilities or personnel in an R&D role for developing new products or production processes? (This is separate from any teaching role they may have). Yes/No**

   5.1 If yes, could you please provide and example of using TAFE in this R&D role?

# 3 Industry association survey

These questions relate to the more advanced production process involving TAFE trained employees in manufacturing.

1. **Are you satisfied with how up to date TAFE equipment is for meeting your technology teaching needs? Yes/No**

   1.1 If not why not?

   1.2 What can be done to improve the technical standards of equipment?

2. **Are you satisfied with the level of qualifications and theoretical and practical skills of TAFE teachers? Yes/No**

   2.1 If not why not?

   2.2 What can be done to improve the level of skills of TAFE teachers?

3. **Are you satisfied with Training Packages in terms of keeping up to date with new technologies? Yes/No**

   3.1 If not why not?

   3.2 What can be done to improve the Training Packages?

4. **One of the key findings from the survey of TAFE teachers is that they identify a number of barriers to maintaining the currency of their technical knowledge and skills. Could you please comment on these barriers?**

   4.1 The first was reduced staff numbers which reduced their capacity to participate in return to industry programs and their capacity to establish networks with firms?

   4.2 Secondly, reduced student numbers in many traditional trades also made it difficult to get funding to update equipment

   4.3 Thirdly, the removal or reduction in central agencies involved in technology information collection and dissemination was seen as producing inefficiencies by devolving this job onto teachers and so resulting in a duplication of effort.

   4.4 Fourthly, the introduction of competition between intrastate and interstate colleges for training contracts was seen as creating disincentives to the sharing of knowledge between colleges.

   4.5 Lastly, Competency Based Training was seen as reducing the scope for imparting the theoretical underpinnings of production processes.

National Centre for Vocational Education Research

Australia's innovation capacity is, in part, reliant on its teaching workforce—to teach and promote new technologies to industry. This pilot study examines how VET teachers, in particular TAFE teachers, maintain the currency of their skills and knowledge base. It also explores their role in the development and diffusion of innovative practices and new technologies in the manufacturing sector. Despite the lack of recognition of TAFE teachers in national innovation policies and programs, they do provide a technology diffusion function. However, there are impediments to maintaining the currency of teacher skills and equipment, including inadequate capital expenditure on equipment, an ageing teaching workforce and reduced access to professional development and return-to-industry programs.

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